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KINGDOM OF SIAM

MINISTRY OF AGRICULTURE.

GENERAL REPORT

ON

IRRIGATION AND DRAINAGE

IN THE

LOWER MENAM VALLEY.

BY

J. HOMAN VAN DER HEIDE.

Engineer of the Waterstaat of Netherlands India, temporarily placed at the disposal of the Siamese Government.

Printed by order of H. E. CHOW PHYA DEVESR WONGSE WIWADT,
Minister of Agriculture.

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* * *

PREFACE

TO THE PRINTED REPORT.

In the present Report the results of a busy period of investigation and travelling in Lower Siam are land down.

The Report was written for the Siamese Government, so a great many of the particulars concerning the country could be considered as already known to the readers and therefore were simply referred to or hinted at.

When however H. E. the Minister of Agriculture ordered the Report to be printed, it was thought fit to insert some explanations and add some notes on behalf of such readers as are little or not aquainted with Siam.

Moreover a few statements were elaborated according to information obtained or papers received after the Report had been forwarded.

As I had to write the Report in a foreign language, I beg the forbearance of the English speaking reader for such linguistic constructions as he finds perhaps somewhat strange. The Report is, of course, to be considered from a technical, and not from a literary point of view.

Finally I wish to state that I am greatly indebted to Mr. A. Cecil Carter, M. A. Director of King's College, Bangkok, who kindly assisted me in revising the proofsheets and in the mean time applied such linguistic corrections, as seemed desirable for a clear understanding.

J. HOMAN VAN DER HEIDE.

Bangkok, June 1903.

Bangkok, *January 24th, 1903.*

To

HIS EXCELLENCY

THE MINISTER OF AGRICULTURE,

BANGKOK.

SIR,

I have the honour to lay before Your Excellency the accompanying General Report on Irrigation and Drainage in the Lower Siam Valley.

In this Report are laid down the results of my investigations into this matter during my now eight months stay in Siam.

Besides in elaboration and studying records and papers available and inquiring for information in various places, this period has been spent principally in travelling in the regions concerned and in performing observations with regard to the rivers.

As the records available were rather scarce, the regions concerned very extensive and travelling in many cases rather slow in Lower Siam, my investigations of course could not but bear a general and provisional character.

This must be taken into consideration in the first place in regard to the accompanying Report, which of course is not meant to give any detailed plan, but only to show the possibility and utility of adequate irrigation and drainage in Lower Siam and to indicate the outlines of the principal scheme, in order to form a basis of provisional consideration for the Government, and further to point out the direction in with plans should be made.

I should here like to state that only Your Excellency's keen interest in the matter and the great help and assistance I have received from the officials of the Departments belonging to Your Ministry, as well as of those of several other Departments and of the Interior Administration, have enabled me to investigate the matter so far as the Report shows, in this somewhat short space of time.

Specially I am indebted to Mr. W. A. Graham, Director of Land records, Mr. R. W. Giblin, Director General of the Royal Survey Department, Mr. H. Gehrts, Director General of Railways, Mr. E. Ambrose, Assistant Director General of the Custom Department and Dr. Yai Suapan Sanit Wongse, Acting Director of the Siam Canals, Land and Irrigation Company, for most kindly procuring me the records, maps and much most valuable information, referring to the matter, and other most useful help.

I have the honour to be

Your Excellency's obedient servant,

(Signed), J. HOMAN VAN DER HEIDE.

GENERAL REPORT

ON

IRRIGATION AND DRAINAGE

IN THE

LOWER MENAM VALLEY.

Introduction. In all matters of irrigation and drainage the main object is the increase of the regular produce of the soil, although other considerations, such as communications and sanitation, may also be of great importance in any such scheme.

The economical results desired are principally to be obtained by means of agricultural operations; it is therefore necessary to discuss the question not only from the technical, but also from the agricultural and economical points of view.

When the subject is considered in reference to a particular case, the following questions immediately present themselves:

1. Is an irrigation and drainage system possible in the region under consideration, that is to say, is a considerable quantity of water available and is the situation and elevation of the land suitable for the purpose?
   For if there is no possibility of irrigation all discussion is superfluous.
2. Will irrigation and drainage be of utility to the country, that is to say, will the result undoubtedly be an increase of the produce of the soil?
3. Are such ameliorations required as regards the country concerned, that is to say, do the economical conditions of the country render an increase of the produce necessary. ?

I intend to discuss these questions successively is the first three sections of this Report, principally with regard to the lower provinces of the valley of the Menam Chow Pya and the adjacent plains of the Bangpakong and the Meklong rivers,*

---

* The Menam Chow Pya is the most important river of Siam from every point of view. The river begins to bear the name above mentioned at Paknampo, the junction of the Nam Ping, or Raheng river, and the Nam Po, its principal tributaries.

The Nam Ping drains a rapidly sloping comparatively narrow valley and the adjacent, mountainous regions and shows somewhat the character of a torrent, running through a wide and shallow bed. A sudden rise and fall of some feet in a few hours, which is enormous for Siam, not infrequently occurs and in the dry season the river is only navigable for very shallow craft.

(See next page.)

and upon the conclusions therein arrived at to base the proposals contained in the subsequent sections of this Report.

Although the other parts of the Kingdom will not be taken particularly under consideration, it must not therefore be inferred that irrigation and drainage works are not available or desirable in those parts, but only that I consider it as being taken for granted that the Lower Menam Valley is the most important and most densely populated part of the Kingdom of Siam, so that such improvements in those regions will be profitable to the greatest possible part of the people and at the same time best serve the interests of the Government.

I.

POSSIBILITY OF IRRIGATION.

With regard to the first question, *i. e. whether an adequate irrigation and drainage system is possible in the Lower Menam Valley and the adjacent plains*, the slope of the soil and the available quantity of water must be first taken into consideration.

The Nam Po unites the slow waters of the Pitsanulok and the Swankalok riverd. These, which are frequently interconnected, drain the extensive and flat upper parts of the Menam plain and the adjacent hill regions. In the plain they show quite the character of lowland rivers, their water running calmly through deep beds, and thanks to the storage capacity of the annually inundated swamps in the lowest part of the plain, they have a very regular régime. Both are navigable for a good distance upstream even in the dry season. From the regularity of the régime of the main river it must be inferred that the Nam Po is of much greater importance with regard to discharge than the Nam Ping.

Below Paknampo the united main river runs through the lower plain. At Ban Klong Kiew, and at Ban Tahkwai, the main river gives part of its water to the Supan and Lopburi rivers and at Chainat to the Menam Nawi. The former runs nearly parallel to the main river and joins the sea near Tachin. The Lopburi river joins the Pasak river at Ayuthia and, together with this river, falls back into the Menam Chow Pya again. The Menam Nawi also joins the main river again.

About 250 K. M below Paknampo, near Paknam, the main river falls into the Gulf of Siam.

The Menam Chow Pya carries down a great quantity of silt and sand, derived from the slate and sandstone formations of its catchment area and at its mouth has deposited an enormous bar, which is a great impediment to navigation.

(See next page.)

Slope of the land.

In the first place it must be observed that the plains of Lower Siam are almost entirely flat, in the sense that there are scarcely any spots on these plains that are raised even insignificantly above the surrounding fields.*

To determine the general slope of the land requires data as to the elevation of the ground and the distances between a member of places suitable for the purpose. The distances are easily to be obtained from the existing maps made by the Royal Survey Department. Figures showing the elevation however are very scarce in these maps; but by adding to the figures in the maps the results of the levellings of the Royal Railway Department and the figures contained in the statements of Mr. J. Mc. Carthy's book "*A Survey in Siam*" (private edition), it was possible to gather, and even sometimes to compare, sufficient reliable data to form general ideas about the matter.

To begin with the principal plain, that of the Menam Chow Pya, according to the maps of the Royal Survey Department the heights above sea level at low

---

The Pasak river drains the long and extensive valley to the east of the Nam Po area and joins the Menam Chow Pya so far downstream that, from a point of view of watersupply, it has to be considered quite seperately.

The Bangpakong river receives its rather sluggish water from an almost perfectly plane catchment area of very gentle slope, bounded on the west by the Menam valley, and on the other sides by low hill ranges.

The Meklong river derives its supply from the extensive, rather high, densely wooded hill ranges and narrow valleys west of the Menam valley and runs with a considerable fall and a fast current through the plain west of the plain of the Menam Chow Pya.

The Menam valley may be devided into two parts, an upper part, to the north of the hill ranges about Paknampo, and a lower part, to the south of these hills. The latter part, which may be spoken of as the Lower Menam Valley, is the very heart of Siam and will here come most under consideration.

---

* The whole Lower Menam Valley and adjacent plains show in all respects the most regular type of a river deposited alluvial formation, with a fairly a uniform, slowly decreasing slope, with the rivers running on ridges, and swampy tracts in the lowest parts between. The soil is clayey, more or less mixed up with quartz sand. The substratum is a marine sand formation.

The plain, where not cultivated, is chiefly covered with jungle grass, where herds of elefants feed upon, brushwood and bamboo. Extensive forests do not exist. Except in the highest tracts along the rivers, even clumps of trees are scarce, apparently in consequence of occasional floods and want of proper drainage.

The coast is flat with a broad muddy shore and is covered with mangrove trees and further inland with nipa grove. There is continuously a slow increase of the land. Dunes and lagoons do not exist along the coast of Lower Siam.

water for the undermentioned places and the distances in a straight line between them are as follows :—

		Height above the ebblevel of the sea (in M.)	Difference in height between the subsequent places (in M.)	Distance in a straight line between the subsequent places (in K.M.)	Slope of the land between the subsequent places.
Main river.	Paknam	4·5	—	—	—
		—	1·5	20·5	1/13,700
	Bangkok	6	—	—	—
		—	5	68	1/13,600
	Ayuthia	11	—	—	—
		—	9	74	1/8,200
	Muang In	20	—	—	—
		—	6	51	1/8,500
	Manorom	26	—	—	—
		—	6	36·5	1/6,100
	Paknampo	32	—	—	—
		—	—	—	—
Pitsanulok branch.	Paknampo	32	—	—	—
		—	7·5	80	1/10,700
	Pichit	39·5	—	—	—
		—	7	41·5	1/5,900
	Pitsunalok	46·5	—	—	—
		—	7	55	1/7,900
	Pichai	53·5	—	—	—
		—	7·5	35	1/4,700
	Uteradit	61	—	—	—
		—	—	—	—
Savankolok branch.	Paknampo	32	—	—	—
		—	29	183·5	1/6,400
	Savankolok	61	—	—	—
		—	12	24	1/2,000
	Bang Hatseo	73	—	—	—
		—	—	—	—
Raheng branch.	Paknampo	32	—	—	—
		—	65	98	1/1,500
	Kampengpet	107	—	—	—

The reliability of the figures of the Royal Survey Department, in some cases is proved by the results of the levelings of the Royal Railway Department. For instance, the difference in height between Bangkok and Paknampo is 23·8 M. according to the railway survey and 26 M. according to the records of the Survey Department. The difference between these data is satisfactorily explained by the fact that the railway survey begins at the top of the railwaydam in Bangkok and ends in Paknampo at a considerable distance from the river, thus beginning at a higher level and finishing at a lower level than the points taken by the Survey Department, which were on the banks of the river.

It is evident from the above-mentioned figures that from Paknampo down to the coast, the slope of the soil of the Menam Valley in the direction parallel to the main direction of the river is successively about 1/6,100 over a distance of 36·5 K. M., 1/8,500 over 51 K. M., 1/8,200 over 74 K. M., 1/13,600 over 68 K. M. and 1/13,700 over 20·5 K. M. About 1/14,000 may therefore be considered as the slightest slope of the Lower Menam valley. The Upper Menam Valley has a greater slope; the least rapidly sloping part, the plain of the Pitsunalok river between Paknampo and Pichit, appears to have a slope of about 1/10,700.

Besides the slope along the main direction of the Menam Chow Pya, there is also a slope across that direction, because in the plains of Siam the rivers and river branches have their course on ridges, built up by the deposits of the overflowing water at flood time, as is generally the case under similar circumstances.

The slope transverse to the main direction of the river is easily perceivable in the existing klong (canals) running in that transverse direction, from the fact that with stagnant water, i e. horizontal water-surface in the klongs, the banks rise considerably higher above the waterlevel towards the ends than in the middle.

The longitudinal section of the Petchaburi railway shows the same fact in a very conspicuous and most exact way with regard to the plain on the left bank of the Meklong river, where in a distance of 10 K. M. there is a fall of 6 M. In general however the transverse slope is small.

When the slope of the soil is rapid enough to be sufficient for suitable irrigation and discharge canals, then adequate works can be carried out without special difficulties, because the surface slope of the canals then can in general be taken parallel to the slope of the ground and no expensive deeply excavated or highly embanked canals are required.

To such as are acquainted with hydrotechnical matters, it is unnecessary to point out that the construction of irrigation and discharge canals in a country that has a slope of at least about 1/14,000 as is the case in the Lower Menam Valley, is not a matter of insuperable difficulty.

The slope here mentioned is more than sufficient for canals with the considerable capacity, which all principal canals for the very extensive Lower Menam Valley indisputably ought to have. In such canals this slope would in general cause a current of a velocity sufficient to prevent the depositing of silt to any considerable extent.

In general the slope of the water-surface of canals to be constructed in the Lower Menam Valley can therefore follow the slope of the soil, which is the least expensive method of canal construction. In the highest parts the slope of the land is too rapid so that a few artificial falls will be required.

That the slope of the soil in the lower plains of Siam is really sufficient for adequate canals will be obvious, even to strangers in hydrotechnical matters, when taking into consideration the fact that the surface slope of the principal rivers of the country is considerably slighter than is the slope of the land, for in general over their whole course through the plain the fall of the rivers is about the same as the fall of the land and their channels are so extremely winding that in many cases the course of the rivers is from one and a half times to twice as long as a straight canal in their main direction would be. Nevertheless these rivers have in general a very strong current and are not liable to silt up.

With regard to the distributary canals by which the water, carried on by the main canals, has to be distributed and conducted to the fields, the slope athwart the main direction of the principal rivers will be of much use, combined with the slope parallel to the rivers, and the elevation of the water-surface of the main canals above the level of the land. In general, to get a sufficient slope, the direction of these distributaries when constructed must meet the main canals at acute angles but, in consequence of the slope athwart, the angles can be made less acute than would be otherwise necessary, which tends to shorten the length of the distributary canals and thus decrease their cost; but this is matter of detail to which I merely refer in passing.

It may be worth while to point out that there are several examples of canals and irrigated plains with about a similar or smaller slope than that of the Menam Valley. The Nile Valley from Assuan to Cairo, for instance, has a general slope of about 1/10,000 to 1/11,000 and the inundation canals in that valley have rarely, if ever, a greater slope than 1/20,000 ("*Irrigation works in India and Egypt*" by R. B. Buckley p. 22-25.) The Nile Delta has over a distance of 220 K. M. an average slope of 1/12,500, whilst the average slope of the Lower Menam Valley is 1/9,500 over the lowest 200 K. M. The Ganges Valley in Bengal has a general slope of about 1/12,000 (l. c. p. 101, decreasing to 1/20,000 (l. c. p. 35.)

The inundation and irrigation works in the Nile and Ganges plains are recognised as among the greatest and most successful of the world.

The regions adjacent to the Lower Menam valley, the irrigation of which should be at once considered, may be enumerated as follows :—

The plain of the Pasak river has, from Chaibadan (54 Meter above sealevel) to Saraburi (21 M. above sealevel) in a distance of about 60 K. M., a fall of about 33 M. i. e. a slope of about 1/2,000, and from Saraburi to Ayuthia (11 M. above sea level) in a distance of about 50 K M., a fall of 10 M. i. e. a slope of 1/5,000.

Although the Pasak river is a tributary of the Menam Chow Pya, it must be treated seperately, because it joins the main river too far downstream to be connected with an irrigation system from the great Menam.

The plain of the Meklong river has, according to the surveys for the Petchaburi railway, from Ban Pong (16 M. above sea-level) to Ratburi (10 M. above sea-level) in a distance of 30 K. M., a fall of 6 M. i. e. a slope of 1/5,000.

The plain of the Bangpakong river has from Krabin (20 M. above sea-level) to Prachim (9 M. above sea-level) a fall of 11 M. to a distance of 40 K. M., which makes a slope of 1/3,600, and from Prachim to the coast the fall is about 6 M. and the distance 80 K. M, thus the slope of the soil is about 1/13,300.

The above-mentioned figures of the levels, as far as not indicated as derived from the Railway surveys and not occurring in the existing maps, are derived from the statements in Mr. J. McCarthy's book "*A Survey in Siam.*"

The velocity of the current in the extremely winding channels of the above named rivers moreover in general also obviously guarantees for these plains the possibility of constructing adequate irrigation canals.

With regard to the discharge of superfluous water it may be observed that if the soil has a sufficient slope to produce a satisfactory current in irrigation canals, the same in general will be the case with discharge canals.

In the lowest tracts of land between the ridges along the main rivers the slope parallel to the main direction of the rivers is about the same as the slope of the ridges. The natural site of the drainage canals lies in these tracts, whilst the supply canals are as a rule located along the ridges, so that in general the drainage channels will meet with about the same slope as the irrigation canals.

On approaching the coast however this is no longer the case; near to the coast the transverse slope ceases to exist and the paralled slope gradually decreases; but even the lowest parts of these regions lie nearly at the level of ordinary high tide, that is to say, about 3 M. above the ordinary low water level of the sea.

The considerable difference (3 to 4 meters) between flood tide and ebb tide will greatly facilitate adequate drainage in these lowest regions; but for the same reason protection against very high tides will be required in certain tracts.

I suppose it may now be considered as sufficiently proved that the elevation and the slope of the ground will produce no particular difficulties against carrying out irrigation and drainage schemes, but, in the contrary, are sufficiently suitable for the purpose.

Further details cannot be stated for want of elevation-records, as special surveys of course could not be undertaken.

*

Available quantity of water.

About the discharge of the rivers no records exist in Siam. The only annotation I found about the matter occurs in Mr. J.McCarthy's book "*A survey in Siam*," and refers to the Mekong river, where he observed in the driest time (March, 1894,) at Chieng Kong a discharge of more than 42,000 cubic feet per second.

Some river-gauge readings have however been performed and recorded during the last years, but with a single exception, not in a sufficiently regular and systematic way to be reliable for technical purposes.

The investigations and observations I made at the end of the last dry season and during the present rainy season with regard to the discharge of the rivers and river branches in Lower Siam showed me that, as far as regards the Lower Menam Valley and adjacent plains, only the undermentioned rivers are available for any considerable water supply for irrigation purposes, viz:—

1. The Menam Chow Pya (which further on briefly will be called the great Menam or Menam only) and her main tributaries, the Raheng, the Savankalok and the Pitsunalok branches and the Pasak river.
2. The Bangpakong river and its main tributaries the. Prachim and Nakon Nayok branches.

   The two main branches of the Prachim river (those of Krabin and Srakeo) are also separately reliable for a satisfactorily regular discharge.
3. The Meklong river.

All other rivers and riverbranches in the Lower Menam Valley and adjacent regions, the Supan and Lopburi rivers not excepted, in the dry season appear to have no discharge or nearly none and in the rainy season no sufficiently regular discharge from their own catchment area, to be suitable to supply any considerable quantity of water for irrigation purposes.

The lower part of the channels of some of these rivers nevertheless are the whole year over more or less filled up with water; but this is either stagnant water derived from the parts of the above mentioned main rivers as far as they are not subjected to tides, or water that is only running up and down by the influence of flux and reflux.

The Petchaburi river, which is duly available for irrigation purposes, is here not taken into consideration as being not directly in an adjacent position to the Menam Valley.

Although the other rivers in the Menam Valley and adjacent plains are not available for the supply of water for irrigation purposes, the above mentioned three main rivers and their tributaries are of high value.

From the information I obtained with regard to the lowest water-level, and from the discharge-determinations I performed at the end of the last dry season in the great Menam in the vicinity of Nakon Sawan and Chainat (catchment area above Chainat 117,000 K. $M.^2$), it must be concluded that the minimum discharge of that river above its confluence with the Ayuthia river in the dry season will be a quantity of about 200 $M.^3$ per second. The maximum discharge at Chainat, according to the discharge determinations I performed, connected with the information I got about the highest flood level people knew of, was in the rainy season of this year about 2,500 $M.^3$ per second; but it may have been 3,500 $M.^3$ in very rainy years, not including the quantity carried off by the Supan river and the Menam Nawi.

It was not possible to ascertain to what extent each of the three principal branches of the Menam upstream of Paknampo contributes to the discharge of the main river.

Although it does not prove very much, it may be of some interest to state that the total quantity of rain, falling in the catchment area of the great Menam above Chainat, amounts to about 5,500 $M.^3$ per sec, reckoned over the whole year and according to the average rainfall of about 1,50 M. per year, derived from the records of the provincial Governors of the northern *circles* (see rainfall statistics).

Specially remarkable in comparison with this figure for the total rainfall is the relatively small maximum discharge of the river, a fact explained by the regularity of the régime.

The minimum discharge of the Pasak river (catchment area about 16,000 K. M.^{2} above Saraburi) could not be closely determined but, according to information, it may be estimated at less than 10 M.^{3} per second.

This rainy season the maximum discharge was about 400 M.^{3} per second, but in ordinary years it may amount to 500 and in very rainy years to about 600 M.^{3}

The Bangpakong river this year appeared to have a maximum discharge of about 800 M.^{3} per second and it seems very probable, according to information obtained with regard to the highest floodlevel ever recorded, that even in very rainy years, the discharge will not much exceed 1,000 M.^{3}

About $^1/_4$ of the discharge of the Bangpakong river comes from the Nakon Nayok branch.

The other $^3/_4$ parts are derived from the Prachim river (catchment area about 14,000 K. M.^{2} above Prachim) and come almost entirely from the two principal tributaries of the latter, the Krabin and Srakeo branches, both of which seem nearly of the same importance, though perhaps the discharge of the latter may be somewhat greater than that of the former.

In the dry season only the last mentioned two tributaries have a regular discharge, which could not be determined but may be for both together, according to information, not much less than 15 M.^{3} per second.

The Meklong river remains to be considered.

The discharge of this river (catchment area about 23,000 K. M.^{2} above Bang Pong) in the dry season will be about 30 M.^{3} per second and the maximum discharge in ordinary years about 1,000 M.^{3} ; and it is to be inferred from information received, that the discharge in very rainy years is not very much more than 1,200 M.^{3} per second.

For irrigation purposes, specially in a rice growing country such as Siam, it is not the minimum discharge which is of decisive importance, and still less is it the maximum discharge ; but the value of a river for irrigation purposes is determined by the quantity of water that is regularly available during the time water is most required for the rice crop, that is to say, at the commencement and at the end of the rainy season.

In this respect the conditions of the rivers above mentioned are very satisfactory.

The general condition in this respect of the great Menam can be inferred, not only from information but more exactly from regular gauge records, kept since August 24th. 1896 at lock Chulalongkorn in the klong Rangsit, and may be described as follows.

In the beginning of May, about 2 or 3 weeks before the rains commence to fall fairly regularly in the lower provinces, the discharge of the Menam successively increases very considerably in consequence of the first regular rains up-country, where the rainy season generally begins earlier than in the lower provinces. After this first somewhat fast rise, the discharge increases continually and very regularly, without any sudden alternations of importance. Sudden great risings and fallings of the water, as is generally the case with rivers in hill regions, do not occur in the great Menam, nor in the other rivers of Lower Siam.

In November, about a couple of weeks after the regular rains have ceased in the lower provinces, the river reaches its highest level, which lasts only a few days, and then the water subsides slowly till the beginning of February, when the time of low water begins again, and lasts till about the end of April. *

The gauge observations at lock Chulalongkorn refer to the waterlevel inside of the canal, that rises and falls with the *high tide level* of the great Menam.

As however in the dry season the level in the canal is higher than the high tide level of the Menam, the gauge is not affected by the rising of the river, until a considerable rise has occurred.

On the contrary, the fall of the river proceeds in the commencement a little less slowly than must be inferred from the scale-readings, but still continues when the canal level begins to become fairly constant.

The annual increase and decrease of the discharge of the Pasak, the Bangpakong and the Meklong rivers occur in about the same way and time as is the case with the great Menam.

In the régime of their rising and falling the main rivers in Lower Siam show general in a very regular character, which is most favourable to irrigation purposes: in consequence of the fact that the rise begins a couple of weeks before the time of regular local rainfall and low water is not reached again until about three months after the cessation of the local rains, the time during which a quantity of water sufficient for the irrigable area is available, is much longer than the local rainy season; and, in consequence of the regularity of the increase and decrease, interruption of the regular watersupply, in the times water is needed most, is not to be feared. Besides this, in consequence of the regularity of the régime, the part of the total flow-off by the rivers, available for irrigation purposes, is much greater than it would be when the risings and fallings were irregular, at least when the storage capacity of the works is comparatively small.

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* « From the King's birthday (September 20th,) to Christmas day ships can generally lie in the river (at Bangkok) on one anchor without swinging, " says Mr. H. Warington Smyth, (who has studied the Menam very seriously in connection with his sailing pursuits) in his book « *Five years in Siam.* " This means a discharge of at least 3,000 M.^{3} per sec. passing Bangkok.

Without continuous series of exact observations during many years it is not possible to state definitely the total quantity of water that can be expected to be available in each part of the year. When however is taken into consideration the maximum and minimum discharge and the régime of rising and falling of the great Menam, then it is surely possible to ascertain a minimum quantity of water, that safely can be admitted as in all cases available during the season of paddy cultivation. According to these considerations the quantity of water from the great Menam that in all safety can be reckoned upon from about the middle of June till about the middle of January will be not less than about 800 M.^{3} per second, whilst from about the middle of May till the middle of June and from the middle till about the end of January usually still more than 500 M.^{3}, and during the time the greatest supply of irrigation water will be required for the paddy cultivation viz: in October, November and December, when the rains become scarce or have ceased, the air is dry and the paddyplants for a great part still are in full course of development, at least about 1,000 to 1,200 M.^{3} per second will always be available.

The Meklong river, the Bangpakong river with its tributaries, and the Pasak river will also be able to supply a very considerable quantity of water for irrigation purposes.

As there are however no reliable gauge observations in connection with these rivers, the available quantity of water for irrigation purposes, they will be able to supply, can only be estimated very roughly.

The first named river is the most important and seems certainly to be credited with a supply of about 200 M.^{3} per second in the paddy growing season and the Bangpakong river would perhaps be able to provide about the same quantity.

The Pasak river will very probably regularly supply some 50 to 100 M.^{3} per second.

The question for what extent of fields the above mentioned available quantities of water may be sufficient, will be treated afterwards, but it may here be observed that the above mentioned *certainly available* quantity of water of the great Menam would suffice to feed the largest irrigation canal that exists, the Ibrahami-canal in Egypt.

The conclusion that the rivers of Lower Siam contain a very great quantity of water available for regular irrigation will, I presume, have been made quite evident by the above explanations.

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Technical possibility

Finally rises, in respect of the possibility of constructing irrigation and drainage works, the question as to the technical possibility of carrying up the water of the rivers to the level of the fields.

For completeness I raise this question, though it is answered beforehand in the affirmative by the mere consideration that the same problem in several countries in numbers of similar or less favourable cases, has been solved with complete success.

The question of the construction of the required works in the case of the great Menam, with respect to the régime of the river and the elevation and slope of the ground, will afterward be treated in general outlines.

The preceding explanations, will have made it evident that constructiug irrigation and drainage works for the Lower Menam Valley and adjacent plains is perfectly possible and will not meet with any particular natural difficulties.

II.

UTILTY OF IRRIGATION.

Comes next the second principal question: *will irrigation and drainage be of utility in Lower Siam?*

In answering this question it is first of all necessary to lay down the definition that irrigation consists in supplying, by artificial means, a certain quantity of water to the fields and drainage in freeing the fields from superfluous water.

Now for an artificial supply of water to be of utility the natural supply must of course be deficient.

To judge the deficiency or sufficiency of natural supply, demands to define previously :—

In the first place the purpose the water is to be used for and the quantity of water required for that purpose and

Secondly the quantity of water produced by natural supplies.

The purpose the water is to be used for in the Lower Menam Valley is for the present principally rice growing.

That rice growing is the most important agricultural occupation in Lower Siam is not an accidental circumstance, but a natural and indispensable consequence of the climatical and hydrographical conditions of the country, as afterwards will be explained.

Importance of rice growing.

Compared with the area under rice crop in whole Siam, the area yielding other produce is of small importance. The fact that the tax on paddy fields is estimated in the State budget for 1901/02 at 2,914,389 ticals, or more than $^5/_6$ of the total landtax, and the tax on all other lands. gardens and plantations at 585,010 ticals, or less than $^1/_6$ of the total amount of the landtax, shows this.

Rice is moreover the staple food of the whole population and furnishes more than $^3/_4$ part of the value of the total exports of Bangkok (i. e. nearly the whole exports of Siam), the average value of the rice export being $ 26$^1/_2$ millions and the average total export $ 34$^3/_4$ millions in the last 5 years (1897-1901).

As the imports must be paid by the money due for the exports, the imports also must depend to a similar degree upon rice growing.

As the rice crop covers at least $^5/_6$ of the arable land, produces the staple food and furnishes more than of $^3/_4$ of the value of the exports, it will surely not be considered an exaggeration to estimate that the total of the national production of Siam depends in a similar degree upon rice growing; and as the wealth of the country in general and the revenue of the Govenment in particular take their origin directly or indirectly from the national production, both national wealth and Government revenue also must directly or indircctly depend upon rice growing in a similar proportion.

It will therefore certainly need no further elucidation that in matters of water supply and drainage, concerning Siam, rice cultivation has to be taken into consideration in the first place and that the interests of rice growing will predominate.

Quantity of water required for rice-fields.

In general fields covered with plants use up water:

a. by infiltration into the soil;

b. by evaporation of the water covering the land or of the water contained in the wet surface earth;

c. by evaporation through the plants and (to a small degree) by the growth of the plants.

The quantity of water required by rice plantations, for the proper development of their growth and for yielding a good crop, therefore depends upon the character and the slope of the soil, the climate of the country and also upon the kind of rice that is cultivated. The required quantity thus may differ for different countries.

In Siam no experiments about this matter have been made, and local data not existing to judge the matter, data must be borrowed from abroad about regions that are in similar conditions.

In Java the matter has been investigated very exactly and repeatedly during many years and at many places. The results of the experiments show that for the plain of Demak the required quantity was found to be less than elswhere, viz: no more than 1.10 Liter per second and per bouw (7,096 $M.^2$), i. e. 1.55 Liter per second and per Hectare, during the period of vigorous growth. *

These figures relate to the very slightly sloping, flat plain of Demak, which lies scarcely above sea-level and has a soil of stiff and little permeable clay that gives no more than an ordinary crop and where the supply through want of sufficient water in general is very spare.

In Italy the lowest definite figure mentioned about the matter is 1·34 Liter per second and per H. A. for the flat clayey part of the Po plain near Lodi.

In British India, Buckley (p. 233) mentions that in Madras the duty of water for rice-lands irrigated by storage works in their immediate vicinity is considered to be 80 acres, i. e. that, besides local rainfall (30 to 40 inches a year), 1 cubic foot of irrigation water per second is required for 80 acres of rice-land, as an average over 185 days; this makes 28 3 L. for 32·4 H. A. or 0·87 L. per H. A. This figure however does not indicate the total quantity of water used for the purposes of agriculture but only the artificial supply in addition to the natural resources. Furthermore it is the average use over a period of more than six months, which is much smaller, than the quantity required by the plants during the time they are in full course of growth.

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* In the plain of Banjoemas (Java) the result of the experiments has been 1·20 L. and in the plain of Tegal 1·25 L. per sec and per bouw. In rapidly sloping hilly regions the quantity of water required generally appears to be much greater; in Buitenzorg for instance as a maximun 3·4 L. per sec. and per bouw is stated over a period of a month.

For large canals in Madras, Buckley mentions the duty of 66 acres. For the Sone canals in Bengal he states a duty of 42 to 45 acres over 12 days during periods of drought (p. 232), The last is about equivalent to 1·6 L. per sec and per H. A.

In the Punjab, where the rainfall is very scanty, (less than 10 inches per year), the quantity of water supplied by irrigation will nearly represent the total quantity required by the crop and the figures given for that country, are therefore of more direct interest. Buckley states for the Sirhind Canal and the Swat river irrigation a supply of 1 cub. foot for 50 and 51 acres, (duty utilised) which corresponds to 1·40 L. per sec. and per H. A. The crop consists however in the Punjab chiefly of wheat, which requires a much smaller quantity of water than rice.

In Egypt the quantity of water required for rice, is taken as 60 $M.^3$ per day, and per acre which is equivalent to 1·70 L. per H. A. and per second.

For Japan Prof. I. Inagaki mentions (in the Bulletin of the College of Agriculture at the Tokyo University), a quantity of 1·5 L. per second and per H. A. as required.

It is obvious from the above-mentioned figures that 1·5 L. per second and per H. A. may be considered as the minimum quantity of water required for rice cultivation during the time of vigorous growth.

When we now take into consideration the special circumstances of Siam, we find the following particulars. Siam is a tropical country and of the above-mentioned countries Japan and Italy lie in the temperate and Egypt and the Punjab, in the subtropical zone, (the data about other parts or India are all complicated with local rainfall), so that the conditions of the Demak plain in Java are most similar to these of Lower Siam. Further it may be taken for granted that in Lower Siam the temperature is rather higher than in the Demak plain, the humidity of the air is rather less than more (the rainfall is about 50% greater in Demak than in Bangkok), and besides there is rather more than less motion of the air in Siam than in Demak, so that the conditions of the three principal agents of evaporation, [temperature, humidity and wind,] are at least as favourable in Lower Siam as in Demak.

It will therefore appear not to be a too venturous conclusion to put the quantity of water required for rice cultivation in Lower Siam as about equal to the quantity required in Demak, viz: at 1·55 L. per second and per H. A.

This quantity of water is equivalent to a rainfall of almost exactly 40 c. m. per month.

It is perhaps not superfluous to remark that the requisite quantities must not be considered as always required and sufficient, but as a minimum required at the time the paddy is in full course of growth, to ensure a proper crop in the given conditions of soil and climate.

It has been proved by numerous experiments that in the early period of the growth of the plants, when the leaves are still small in size and number, and at the later period, when the plants are near to maturity, the required quantity of water is much smaller than during the period of vigorous growth.

When the required quantity is not fully available during the period the plants are in full course of growth, the plants do not immediately die but they will suffer and be impeded in their development by want of water and the crop will become smaller in some proportion to the want. This is the direct consequence of the agricultural law, that the growth of plants is governed entirely by that one of the nutritious substances they require, of which the least quantity is available, so that, when the plants are in want of water, this want impedes their growth, however favourable all other conditions for their development may be. This *law of minimum* is not only scientifically proved, for water equally, but must obviously seem quite natural to everyone who takes the matter into consideration, for it is similar to the fact that a thirsty man is not relieved by giving him a piece of dry bread.

Only when the want of water becomes very pressing the crop will fail entirely. On the other hand an increase of the available quantity, above that mentioned as strictly required during the period of full growth, will in general, when the soil is fertile and the climate favourable, contribute much to a still better growth of the plants and increase of the crop.

Of course it will never occur that the whole of an extensive area of cultivated paddy land will be at the same time at the same stage of growth and would require a full supply of water all over. Especially this will never be the case in Lower Siam where the lots of land cultivated by the farmers individually are very extensive and therefore the period of vigorous growth falls at very different times for the different parts of the crop.

Natural water supply.

The question as to how far the natural water supply of the fields is sufficient to satisfy the wants of agriculture must now be investigated.

The natural supply of a certain piece of land is derived :

a. from rainfall ;

b. from the flow-off of superfluous water from more elevated adjacent fields;

c. from the overflow of natural watercourses.

Rainfall.

The rainfall will first be considered.

The records about this matter are scanty in Siam and with many breaks. All I could gather about the matter is mentioned in the rainfall statistics appended to this report.

The general consequences of these rainfall records may be stated as follows :—

The maximum rainfall per year recorded in Bangkok has been 194·36 c.m. in 1845 and 177·98 c. m. in 1889, and the minimum per. year 85·75 c. m. (in 1884). The average for ten years (1882-91) was 130·20 c. m.

From the great difference between the maximum, the minimum and the average, it may be inferred that the rainfall in Bangkok can be very irregular.

A comparison with the undermentioned rainfall statistics over 1889-98 of eleven rainfall observation stations in the rice growing regions of Java, which contain an exceptionally dry year (1891) and two exceptionally wet ones (1889 and 1895), shows that differences as stated for Bangkok are rare in Java.

RAINFALL IN C. M.

Places in Java.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898
Serang	187·3	169·4	117·3	212.6	194·9	162·5	183·8	141·0	157·9	216·7
Bandong	181·6	154·4	151·8	203·3	153·4	201·0	166·4	175·0	211·8	161·6
Cheribon	302·7	167·6	no rec.	244·9	236·2	197·4	255·7	262·0	210·7	222·0
Banyoemas	375·5	298·8	182·5	378·7	317·3	315·8	282·3	294·1	249·4	334·0
Pekalongan	128·3	140·2	89·0	243·6	222·6	215·0	263·7	228·0	203·2	241·4
Semarang	193·2	231·5	158·9	243·7	350·5	224·2	280·1	189·5	187·4	147·7
Bodyonegoro	389·2	223·6	140·0	179·3	224·2	no rec.	198·1	201·8	189·7	206·0
Kediri	150·6	160·7	102·2	226·7	198·9	136·9	no rec.	174·9	133·7	135·1
Soerabaya	214·9	165·4	144·3	165·7	172·5	182·8	212·8	192·7	183·2	193·5
Banyoewangi	190·4	231·2	89·0	161·6	121·5	151·1	176·1	114·5	122·3	172·1
Malang	263·7	188·7	155.2	188·4	180·3	161·3	194·3	162.1	186·2	202·2
Average in c. m.	234·—	193·—	133·—	213·—	215·—	195·—	221·—	194·—	185·—	203·—

In general however the annual amount of rain in Bangkok seems not to be so very far from the average.

Whether the rainfall is sufficient or not for the proper growth of the rice crop, does not depend only, or even in principal, on the total rainfall of the whole year. What is required is that the available quantity be sufficient to meet the requirements at each part of the period during which agricultural operations are in progress.

A comparison of the monthly rainfall and the quantity of water required per month during the period of full growth will therefore give a clearer idea about the matter.

Now the quantity required for rice growing is, as explained, at least 1·55 L. per second and per H. A., which is equivalent to a rainfall of 40 c. m. or 15·8 inches per month, whereas from the appended rainfall records, it appears that in the of 3 years the missionary's records relate to (1845-47), only in one month was the rainfall equivalent to the required quantity; in the period of ten years the Borneo Company's records relate to (1882-91), only in 2 months; and in the eight years period of the records of the Royal Railway Department (1894-1901), only 3 months, of which two cases occur in the hill regions (Muaklek and Hinlap) and one in the plain (Lopburi). In the rainfall statistics the months for which rainfall exceeds 40 c. m.=15·8 inches are put in brackets.

In the statements about the averages of the records of the provincial officials, the monthly rainfall reaches 40 c. m. only 8 times, of which 7 cases refer to provinces outside of the Lower Menam Valley.

The average rainfall per month however for the 10 years period of 1882-1891, even in the most rainy month of September, does not amount higher than 28·90 c. m. and in all other months the average rainfall is even much below this figure.

Thus from the above rainfall records, though they may be incomplete, sufficient information can be gathered, as far as the natural supply of water is concerned, to justify the inference that in the lower Menam plain the rainfall in ordinary years, even in the most rainy month, is quite insufficient to satisfy the requirements of a properly growing rice crop.

The deficiency is rendered more stringent by the circumstance that the farmers in Lower Siam in general work such extensive lots of land that they cannot cultivate them but in a gradual way and so the period of vigorous growth and highest requirements for a small part of the crop only falls in the height of the rainy season.

In years of scanty rainfall this deficiency is very apparent and reaches such a pitch as to cause entire failure of a large part of the crop; only in very rare months in extremely rainy years does the rainfall appear to be quite satisfactory.

In respect to water supply by rainfall, it must always be considered that the whole quantity of the rainfall is never available for cultivation, because, in consequence of the irregularity of the rains, a part of the downpour is always lost by draining away over the surface of the lands. Whatever care people may take to retain the rain water, it is practically impossible to prevent a part being lost during temporary heavy showers. The total rainfall has therefore to be reduced by a certain percentage to get the real quantity available for cultivation.

It is further a matter of interest that, according to the averages of the rainfall records of the provincial officials and of the railway officials, in the provinces of the Lower Menam Valley the amount of rain is considerably less than in the Northern provinces (Upper Menam basin) and than in the hill regions between the Menam and the Mekong basins.

Comparison of the average rainfall figures for Muaklek and Hinlap (149·78 and 169·23 c. m.) with the records of the stations in the plain (Bangkok 130·20 c. m., Lopburi 115·33 c. m., Ban Pong 119·51 c. m., Ratburi 84·03 c. m.) shows the last, and comparison of the average rainfall of the Northern provinces (149·24 c. m.) with that of the Lower Menam Valley (121·01) shows the first fact obviously.

In the South Western provinces (average (221·35 c. m.) and in the South Eastern provinces (average 252·22 c. m.) the rainfall also appears to be much greater than in the Lower Menam Valley (average 120·01 c. m.)

The records of the provincial officials (after being purified from obvious errors and the faults being further partially eliminated by the calculation) agree sufficiently with the records of the Borneo Company for 1882-1891, of the Railway officials for 1894-1901 and of the British Consulate at Chiengmai for 1898-1900, as to inspire confidence in their reliability as averages.

The people seem also, as I was informed, generally quite conscious, of the fact that rainfall is much smaller in the Lower Menam Valley than in the regions to the north, east and west.

This fact can indeed be explained very rationally by the functions of the high western hill ranges. which retain the humidity of the south west monsoon, so that in Tenasserim and Pegu the rainfall is more than 100 inches, (Buckley's rainfall map) that is about twice as great as in the Lower Menam plain. The influence of these hill ranges decreases as the distance to the east increases and also with increasing elevation of the adjacent regions and so the rainfall must naturally be much smaller in the Lower Menam Valley than in the hills at the east side of the Valley and than in the Upper Menam basin.

Similar circumstances explain the fact that the annual rainfall in Chantaboon at the west side of the hill ranges along the east coast of the Gulf of Siam, amounts to 300 c. m. and in Pnom Penh, at the east side of these hill ranges, measures 133 c. m. only, according to the statements in the *Bulletin Economique de l'Indo-Chine.*

From these particulars may be clearly deduced that in the Lower Menam Valley rainfall is deficient, with regard to water supply for rice cultivation, to a considerably greater extent than in the other parts of the country I have mentioned.

Flow-off from adjacent fields.

The question of the second source of natural supply, that is the flow-off of superfluous water from the more elevated adjacent fields to the fields at a lower level, may be dismissed in a few words.

When the general rainfall is insufficient in a certain tract, then this will as a rule also be the case for the adjacent fields and should the rainfall be insufficient for these adjacent fields themselves, it is unlikely that there will be any superfluous water flowing off from them to other fields.

When in consequence of a period of heavy showers the whole of the water cannot be retained, then only will there be any flow-off to other fields at a lower level: but in general it will be precisely at that time that these lower fields are themselves subjected to the heavy showers and therefore the water obtained by flow-off is useless and unnecessary.

The flow-off will therefore occur during a period of heavy rains when it is unnecessary, and fail entirely during periods of scanty rainfall, when it is most needed for the fields at a lower level.

When the adjacent elevated lands are jungle, the same difficulty remains because certainly the jungle grass with its great surface of leaf also requires a great quantity of water for its growth, so that no flow-off can be expected, except at periods of extraordinary showers when the flow-off is of no direct utility to the fields situated on a lower level.

In the case of jungle the flow-off will however in general be not as small as in the case of cultivated paddy land, because in the jungle no care is bestowed on retaining the water by embankments or ditches.

That we do not hear complaints about want of water with regard to jungles, is evidently not caused by non existence of this want, but because men do not interest themselves very much about jungle. If elephants however could be heard in the case, they would probably not fail to complain about the dryness of their food caused by want of sufficient water.

The flow-off of adjacent fields, cannot therefore in general be expected to provide, to any considerable degree, for the deficiency of rainfall.

Only when the whole of the drainage water of an extensive region, specially of jungle, can be gathered on a small tract of cultivated land and is pervented from being drained off further, as sometimes is the case, a real, though very limited effect can be expected from this supply.

The area that can be supplied by the drainage water of more elevated regions however is always small in proportion to the area drained off, and this will be particularly the case if the drainage area is close by and relatively small itself; so only a very small part of the country can be benefitted by neighbouring drainage and as a general remedy against want of water this supply is of no importance.

This source of supply moreover for the benefitted tracts also soon flows scantier in proportion to the deficiency of the local rainfall, as the neighbouring rainfall in general will be deficient at the same time.

Overflow of natural watercourses.

There remains the overflow of natural watercourses, as a source of natural supply of water.

This source of supply refers to the principal water courses which cross the regions concerned without directly affecting the drainage of the locality.

This overflow is however, in the alluvial plains, confined to very rare floods of most extraordinary height and very short duration, which in general occur in years and at times during which the local rainfall also is extraordinarily great and thus this supply of water is least required.

It will easily be understood that this must be the case, because the rivers, by whose deposit the plains are formed, have a natural tendency to raise their banks, by continual fresh deposits, retained by the vegetation on the banks, as high as the highest flood; and when the flood regularly reaches a certain level for any considerable duration, as the very regular régime of the rivers causes to be the case in Lower Siam, the deposits retained by the vegetation on the banks, will soon grow high enough and form natural embankments which prevent further overflow, except by very rarely occurring extraordinary high floods, when overflow will be of little use to the fields. This has the sooner been the case here, because the rivers in Siam in general carry down a very great quantity of silt and have a very regular régime, so that as a rule the banks of the rivers in Lower Siam have reached the height of ordinary high flood level.

Only when the water of a river contains very little silt or in the case of tracts of land that are enclosed and surrounded by more elevated regions in such a way that the water flowing over the banks of the river on the land by high flood cannot run off by any other means, but becomes quite stagnant on the inundated tract, the flooded banks will not be raised very quickly and inundation by overflow may practically be of rather permanent duration. This seems to be the case with the lower part of the Nakon Nayok river and a small tract of land along the Bangpakong river.

In general however, in consequence of the rapid rising of the banks, in times of ordinary high flood, [and still less in times of scanty rainfall when supply is most required] the level of the rivers does not rise above the banks for any considerable time and to any considerable height and therefore overflow of natural watercourses in Lower Siam is also of little or no avail to fill up the deficiency of the rainfall in respect to water supply for paddy cultivation.

The above conclusion is rather contradictory to a traditional opinion in respect to the flooding of the fields by the rivers, but nevertheless is as exact as it is natural. The extent of land flooded by the rivers by overflow of the banks, if any, makes a quite insignificant factor in Siamese paddy cultivation.

In reality the natural supply of the bulk of the paddy fields in Lower Siam depends upon rainfall only, and for a small part of the lowest lands, besides local rainfall, drainage of more elevated neighbouring regions is a second source of supply.

Present artificial water supply.

As a general conclusion from what has been explained with regard to the natural supply it may therefore be stated, that the average rainfall in Lower Siam, specially in the Lower Menam Valley, is quite insufficient to provide for the want of water of a properly growing rice plantation and that flow-off from more elevated adjacent fields and the overflow of natural watercourses in general for the bulk of the fields do not fill up the deficiency of the rainfall. Still less do they do so when the local rainfall is most deficient.

As the growth of the crop must consequently be impeded by want of a sufficient natural supply, artificial supply of water for rice growing must be regarded as being of great utility for rice cultivation in the Lower Menam Valley.

This fact is already well known by experience to the Siamese for a very long time and efforts have been made to counteract, as far as possible, the deficiency of rainfall by cutting a number of canals (klongs) across through the ridges by which the rivers are prevented from overflowing, and so the now existing primitive artificial watersupply has been created. These canals as a rule run in a direction about transverse to the main direction of the principal rivers; they interconnect these rivers many times and spread their branches over the country in all directions so as to intercommunicate with each other also; and so these canals at the same time have become the general means of communication.

This most evident way of supplying water to the fields presented no technical difficulties in its execution and thus could easily be adopted to a considerable extent in the lowest parts of the Lower Menam Valley; but with simpleness in execution this method of artificial watersupply combines smallness of effect, specially with regard to the supply.

It is obvious that the effect could not but be small, because the level of the water in the canals is dependent on the water level of the rivers and as the rivers during many centuries have raised the ground along their course to the height of ordinary high flood, the water in the canals can reach the level of the fields in the vicinity of the rivers only in times of extraordinary high floods, which occur at very rare intervals in years of abundant rainfall only, and then but for a very short period.

Now the deficiency of these canals is met in some way by the slope of the soil athwart the main direction of the rivers, but when the canals have to carry water from the rivers in any considerable quantity, a slope of the water level in the canals is required for that purpose also, which counterbalances the favourable circumstance of the soil sloping in the direction of the canals.

The result of all these cirumstances is as follows :—

The fields in the immediate vicinity of the rivers are only flooded during a couple of days or so by very rare, and exceptionally high floods, which occur perhaps not more than once in many years, at times when local rainfall generally is abundant also and supply least required.

Broad tracts of land at some distance from the course of the rivers are flooded in ordinary years only during the time of very high annual floods; this flooding lasts only from a few days on the higher, to a few weeks on the lower fields. According to the inquiries I made in the matter, a considerable part of the fields that are commanded by the canals are only flooded during four or five days, in years when the rivers reach their ordinary high level. Another strip of land, more distant from the rivers, has a flooding of 10 to 14 days in ordinary years and at a still greater distance the flood may last for a month and so on.

Only the fields situated in the lowest tracts, midway between the great Meman and the Supan, the Meklong and the Bangpakong rivers are flooded during a sufficient space of time (about three months or more) to make the success of the crop tolerably sure, but only, if it has been possible to cultivate the fields in due time.

The flooding of these most favorably situated fields begins generally in September, about a month before the cessation of the regular local rainfall, so that for labouring the fields, sowing, planting and the first period of growth in ordinary years even the best flooded fields depend upon rainfall only, in the same way as the higher lands and are liable to the same difficulties, with regard to failure or irregularity of the rains.

In years of scanty rainfall, moreover, the level of the rivers does not reach its ordinary gauge and high water is of shorter duration so that, when most wanted, the supply by the klongs is most deficient.

Drawbacks of the klong system.

The flooding in the lowest tracts of land is not entirely owing to the rivers, but partly, especially in the commencement, when the rivers have not yet risen to their highest level, to the fact that all the water drained off, in consequence of the irregularity of the rainfall, from the higher parts of the whole regions between the main rivers, is gathered in these lowest tracts.

The natural drainage line of these tracts is in a southern direction, about parallel to the main direction of the rivers; but drainage in this direction is obstructed very much by the embankments of excavated earth along the existing klongs running transverse to this direction. Though these embankments are not intentionally constructed, but raised in a rather irregular and often interrupted way to get rid of the earth only, they nevertheless have a very active part in the retention of the drainage water in the lowest tracts midway between the main rivers.

At the period before high flood time the canals, which are in open communication with the rivers, act in a way contrary to what they are constructed for viz: they carry off the water from these lowest parts to the rivers and so, by lowering the level, prevent the extention of the flooding to as large an area as otherwise would be possible.

During this time the surface of the water in the klongs slopes from the middle to the ends, so that in the middle parts at the places where the soil is lowest, the water level is highest and on the contrary at the end parts, where the soil is highest, the level is lowest; this is as great a disadvantage for the lowest fields, which are liable to be flooded too deep at the time the paddy plants are still small; as for the higher fields, which get no water at all.

In the same way, the klongs act as discharging canals when the rivers are subsiding Then they carry off again from the fields the water which they previously conveyed there. in the same proportion as the water in the rivers is falling.

As the rivers generally have not yet reached their ordinary highest level at the time when in the lower plains the regular local rains have begun to diminish, so at this time a considerable quantity of water, gathered in the lowest tracts between the main rivers, generally is drained off quite undesired; and as the rivers in general commence to fall a long time before a cessation of flooding is desirable, at that time, also, a quite undesired draining off is caused by the open klongs.

The last mentioned peculiarity of the canals cut across the ridges along the rivers, viz: to drain off the water as well as to carry it on, is therefore often a great drawback.

By scooping and pumping, which is performed on a very extensive scale with various kinds of implements and whereon people spend a good deal of money and labour, the cultivators try to surmount the difficulties, caused by want of water, as much as possible; but only for a small part of the fields in the vicinity of the klongs they succeed in doing so, because even when a man works 10 hours every day at his full force, by pumping or scooping he appears not to be able to provide more than a poor supply for an extent of rice plantation of at best 5 to 10 rais. (1 rai=1600 M.^{2}).

The Rangsit Canal Company * has neutralised these disadvantages by providing the main canal of their system with locks which prevent the water from running away into the river and retain it in the canals. In this manner a great improvement is attained, to which the Klong Rangsit enterprise owes a great part of its success.

Klongs near the coast.

The klongs in the vicinity of the coast are subject to the influence of tide, which has the disadvantage that twice a day the klongs are partly emptied, though also filled up again.

Near the coast, as well as in the inland regions, the water has elevated the soil, by depositing silt, to its ordinary high tide level, and so in these regions flooding only occurs rarely, at extraordinary high tides.

By the daily subsiding of the water in consequence of reflux, here, moreover, the supply of water from the klongs to the fields, if any, is confined to a few hours a day.

The other above mentioned drawbacks connected with the present klong system in general, occur in the case of the klongs near the coast in an aggravated degree, because in consequence of flux and reflux, the opportunity for the water to run away is so much greater.

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* In 1889 the Siamese Government granted a concession for a period of 25 years for digging canals in the jungles between the great Menam and the Nakon Nayok river to the north of the klong San Sep, to a private Company, *the Siam Canals, Land and Irrigation Company*, under stipulation that all the uncultivated lands of the region crossed by the canals to be excavated, to a certain distance at both sides thereof, should belong to the Company.

This Company is digging a system of navigation and inundation canals, after the above described Siamese fashion, to a total length of about 1·200 K.M, which embrace an area of about 240·000 H. A. The main canal, klong Rangsit, connects the great Menam with the Nakon Nayok river and is at both ends closed up by locks, which retain the water in the territory of the Company. The works of this Company, which will be finished in a few years, will open up the whole region concerned and since about 1895 more than half the extent of these 240·000 H. A. formerly uncultivated jungle has gradually been converted into valuable paddy lands, which with regard to watersupply are in better condition than any other part of Lower Siam. The enterprise has proved to be a financial succes.

Another drawback of no small importance of the klongs near the coast is that, principally in the dry reason, they carry the salt water far up country and so spoil not only the water in the klongs for cultivation and drinking purposes, but spoil also, at high spring tides, a good deal of paddy fields in the regions they run through, by inundating them with salt water.

A good deal of this damage has been caused by people digging out and enlarging small creeks, connected with the sea, for the purpose of shipping firewood and attap from the mangrove and nipa forests along the coast. If very small, the current of the tide in these creeks is not strong enough to do much harm; but if they have attained a certain size, according to the experience of some decades, they are growing continually bigger by the action of the tide; the salt water accordingly is encroaching gradually further and its level in the inland reaches is rising higher and spoiling more land every year.

The extent of valuable paddy land spoiled in this way is very important, and may be estimated at about three hundred thousand rais.

Results of the present system.

Even without regard to the last mentioned drawbacks, the Siamese klongs, which may be classed as a primitive kind of inundation canal, form, as was explained, a very deficient system of artificial watersupply, because the supply depends not upon the quantity of water discharged by the river, but upon the level the water reaches in the river, so that in relation to the elevation of the fields, only when the ordinary high level is reached supply is available to any considerable extent, but this occurs only at the end of the rainy season for a few weeks.

In the beginning of the period of regular rains, when the fields have to be laboured, sown and planted, the river level is still low, and no flooding by water from the rivers or by drainage water from more elevated regions is possible, even in the lowest parts of the low tracts of land between the main rivers.

After the rains have continued for a good time, these very lowest tracts generally are flooded by drainage water from the higher regions.

With the exception of these very lowest tracts, during the greatest part of the period of vigorous growth, as well as before, the whole of the paddyfields of Lower Siam practically are dependent upon rainfall only, where there are klongs and where there are none.

Only during the last part of the time of vigorous growth a considerable extent of the land beyond the lowest tracts has a period of flooding, lasting generally from a few days to a few weeks, and at the best a couple of months.

Accordingly the main effect of the present system, though certainly considerable in the localities concerned, is practically confined to the low lying tracts of land of comparatively little extent, situated between the main rivers; it can therefore be of very little importance in respect to the total rice crop of Siam, however numerous the klongs may be in the Lower Menam Valley.

The following comparative statement of the rainfall at Bangkok and the export of rice in the export season, following the year for which the rainfall is recorded, (the export of each year is obtained from the crop of one or two previous years) may sustain this conclusion.

The figures about rice export are produced by Mr. E. Ambrose, Assistant Director General of Customs, and are partly derived from statistics kept at the office of the Borneo Company Limited, Rangkok.

Rainfall year			Rainfall in c. m.		Rice export in Eng. tons.	Year of export.
1882			136·24		158·007	1883
1883			107·21		283·933	1884
1884			85·75		217·179	1885
1885			152·04		215·387	1886
1886			166·55		396·700	1887
1887			140·—		449·800	1888
1888			117·02		254·000	1889
1889			177·98		475·100	1890
1890			124·20		226·500	1891
1891			94·92		203·900	1892
1892	No rainfall records at all could be obtained for Bangkok and no consecutive set of even a couple of years for any other place in the Lower Menam Valley.		—		775·500	1893
1893			—		507·400	1894
1894			—		464·000	1895
1895			—		457·600	1896
1896			[c. m.] 192·91	Korat hill range.	557·700	1897
1897			169·78		519·200	1898
1898		Chiengmai. [inches.] 42·52	168·41		445·306	1899
1899		39·86	163·01		414·400	1900
1900		70·76			682·300	1901

These figures show undeniably a tendency of the rice export to increase rapidly after one or two years of more than average rainfall and to decrease after years of scanty rainfall. That the two statements do not agree year after year with the same regularity may by explained by inaccuracy of the export returns (I was informed by Mr. E. Ambrose that probably the rice export figures for 1893 are to be lessened by about 100,000 tons), by storing up the crop and other actions of commerce in relation with prices, by the difficulties the rice boats meet with in coming;

down to Bangkok and by the circumstance that the rainfall of Bangkok will not be for every year in the same proportion to the average rainfall of the ricegrowing part of the country.

Outside its relation with rainfall, the export shows a general tendency to increase, especially in the period before 1893.

A similar relation as between rice export and rainfall in Siam can be stated between the total crop and the rainfall in Java, as the statement given below will show.

In Java the rice for the most part is planted in December and January and harvested in May and June, so that the figures for rainfall and harvest chiefly must refer to the same year.

year.	Average rainfall of 11 places in the principal paddy growing regions of Java in c. m. (see p. 18)	Estimated crop of the provinces under direct Government control in Java in millions of piculs paddy.
1889	234	65·5
1890	193	60.9
1891	133	61·4
1892	213	69·1
1893	215	66·6
1894	195	70·0
1895	221	73·4
1896	194	66·7
1897	185	70·4
1898	203	71·9
—	average 198·6	67·6

With regard to the figures for Java, the fact must be taken into consideration that the annual rainfall in eleven places is not quite proportional to the average annual rainfall of the whole of the rice growing parts of the country and also that the calender year and the paddy growing season do not quite agree.

Nevertheless these figures also show in general an unmistakable connection between rainfall and crop in Java.

In Siam the lowest rice export during the last ten years (203,900 tons in in 1892) is only 26% of the highest (775,500 tons in 1893, or 30% when the export in 1893 is lessened by 100,000 tons) and in Java during the 10 years mentioned the lowest estimate of crop (1890) is 83 % of the highest.

This enormous difference must be attributed partly of course to the fact that in Siam the exported quantity is a part only (but evidently a very great part) of the crop, as also to the fact that rainfall is less irregular in Java, and further chiefly to the influence of irrigation; about 60% of the paddy fields of Java having a more or less regular artificial watersupply.

The agreement between scanty rainfall and small rice export and abundant rainfall and large export and the great difference between small and large rice export shows obviously that upon the whole the existing klong system with regard to the total crop is of little avail to prevent failure of crop by want of water.

This undoubledly results from the fact explained before, that only a small part of the total extent of paddy fields really profits by the watersupply as provided by the existing klongs, whilst moreover the extent of fields served by this supply is smallest when rainfall is scantiest, because then the rise of the rivers is less high and of shorter duration.

The frequent occurrence of failure of a considerable proportion of the crop, in consequence of scanty rainfall, also explains the great value the Siamese cultivators set to having some artificial water supply for their fields, even in the very imperfect way provided by the existing klongs. This is most evident from the difference in price and rent between the fields situated in the lowest strips of land in the middle between the principal rivers and the more elevated land situated nearer to the rivers.

According to the investigations I made into this matter, the land is cheapest in price and rent in the high tracts near the river and the value in general continually increases towards the lowest middle parts, where the flooding is of longest duration.

Without exception the persons interrogated informed me that the reason of the price or rent of land being higher or lower depended chiefly upon the longer or shorter duration of the flooding. The difference in several cases amounts to this proportion that people pay for the lowest lands 9 to 10 ticals rent per rai and for lands near to the rivers only 1 to 2 ticals whilst in the first case the selling price may amount to 80 ticals, against 10 to 20 ticals in the last case.

The few parcels of land which in ordinary years are flooded for a considerable period by the main rivers, are, I was informed, considered especially valuable.

Summing up what was explained, from the great irregularity of the rice export of Siam may certainly be concluded a proportional irregularity of the crop; moreover it may be taken as proved that this irregularity is caused principally by want of water. These two facts show in the meantime, as already mentioned, that the present system of artificial water supply is of little avail with respect to securing a regular general crop and confirm the conclusion that, except in the case of the small strips of land situated in the lowest parts between the rivers and a great part of the Klong Rangsit lands, the paddy fields of the lower Menam plain for their watersupply are practically dependent on rainfall only. In these lowest tracts, [the Klong Rangsit district not excluded], for the labouring of the nursery beds and of the fields, the sowing, the planting and the first period of the growth of the crop, the fields, as was observed, also depend exclusively on rainfall and only for the later period of growth do they, enjoy any artificial supply.

Silt on the fields under present conditions.

Besides what has already been mentioned, there is still another disadvantage of the present system to be pointed out.

It is a general belief among non-expert people that the existing flooding contributes particularly to the fertility of the soil, which belief is founded on the opinion that by the flooding a considerable quantity of silt is carried to the fields.

In general it is taken for granted that the silt of the rivers has great fertilizing power and, though this is not invariably the case, agricultural practice has demonstrated the fact often enough. Moreover a great deal of scientific experiments have been made, for instance by the agricultural stations of Java, with the result that the great manuring value of the silt of numbers of irrigation canals has been proved most conclusively.

In Siam there are no such data but nevertheless the great fertilizing power of the silt of the Menam and the Meklong rivers is evident from the frequently observed fact, that where on a paddy field close to an inlet of water directly from the river or from a running klong, a good deal of silt is deposited, the paddy shows very obviously an extremely luxuriant growth, compared with the surrounding plantations; a fact which can only be attributed to the effect of the deposited silt.

To cause its effect, in any case, the fertilizing silt must of course be carried to the fields, and this, as will be shown, is not at all realised by the existing system of inundation klongs.

Overflowing of the banks of the rivers, it has been explained, can only occur very rarely from natural causes; and when it occurs, nearly the whole quantity of silt carried on by the overflowing water is filtered out and retained by the vegetation (it may be grass or paddy or some other kind of plant) that is growing on perhaps the first 100 M. distance from the bank. Only when the fields are inundated to a level reaching above the vegetation and the water was running over the banks with at least a perceivable current, some deposit of silt can be expected, but the is nowhere the case in Lower Siam.

The fields that get water from the rivers by means of the klongs are in the same condition as if they got it by overflowing directly from the rivers, only with this difference that in general the current in the klongs towards the flooded lower strips of land between the rivers is so slow, that the greatest quantity of silt is deposited on the bottom of the klongs instead of on the fields along the banks. The fact that in general in the rainy season the water of the klongs in the middle parts is quite clear, proves this undeniably.

The fertilising results of the present inundation system are therefore of very limited and unimportant effect.

The fertilising value of inundations in general is very commonly overestimated, because generally people hardly take into consideration the origin of the water and whether the water can arrive with sufficient velocity to carry and spread any solid substances over the fields or whether the water is regularly refreshed.

Conveying fertilising silt in any considerable quantity to the bulk of the fields can in general only be effected by an adequate system of supply (irrigation and inundation) canals that branch off in distributary canals and subdistributaries, all with a current of sufficient velocity to keep at least a great deal of the silt in motion and from which subdistributaries every part of the fields receives directly the required watersupply.

Definition of Irrigation and Inundation canals.

The present situation and its consequences being treated above, now the future posibilities and conditions may be taken into consideration and compared with the present.

Before going on, it may however be of use to define here very precisely what is meant by irrigation canals as opposed to inundation canals.

Those canals are called inundation canals which only draw off water available for artificial supply at a certain rather high level of the feeding river.

These canals can be cut transverse to the main direction of the rivers, as the Siamese klongs in general are and which represent the most primitive and simple kind, or they can follow in principal the main direction of the river, with a less rapid slope than has the river itself, to carry the water on some distance from the off-take at a more elevated level than the river has in the same region. This kind of inundation canal is for instance the principal type of the Punjab canals, and was so too of the Egyptian canals, till in latter years most of them were transformed into irrigation canals. In Siam the Menam Nawi may in some respects be considered as belonging to this last kind of canal.

Irrigation canals are those that can always draw water from the feeding rivers, if the rivers only contain some water. If the rivers, and hence the canals also, carry a considerable quantity of water throughout the year, the canals are named perennial; if this is not the case, they are named seasonal irrigation canals.

Irrigation canals drawn off from the Menam Chow Pya or from the Pasak, the Meklong or the Bangpakong rivers would of course be perennial, these rivers having also in the dry season a considerable discharge.

A thoroughly adequate irrigation system requires not only a system of irrigation canals with distributaries and subdistributaries by which water can be supplied at will to every part of the area under command, but also a drainage system by which from every part of the fields any undesired quantity of water can be drained off, and a system of embankments, formed chiefly by the earth excavated for the construction of the canals, destined to irrigate the fields, on the high ridges along the rivers, which embankments serve to prevent extraordinary high floods from overflowing the banks at other places than those suitable for the purpose.

Advantages of adequate irrigation.

The advantages, which would be connected with an adequate irrigation and drainage system in Lower Siam, will now be considered in comparison with the present circumstances.

Failure of crop.

It has been shown and is generally acknowledged that scanty rainfall is the predominating cause of failure of crop in Lower Siam.

1. In the first place attention must be drawn to the fact, that an adequate irrigation system would provide in the most efficacious way against the considerable shortage of water for rice cultivation, in ordinary times caused by insufficient ordinary rainfall, and especially in the pressing want of water experienced in times of very scanty rainfall. Accordingly failure of crop in consequence of drought would be prevented and a regular crop secured for the regions concerned.

As under present conditions however, the available quantity of water is almost always insufficient, whilst in consequence of adequate irrigation it will be always sufficient, that is to say, much better than at present in the most favourable year, therefore not only a regular but a plentiful crop as well may be expected.

What would be the importance for Siam of these results of a water supply may be inferred from the difference between the average, the minimum and the maximum of the quantity of rice exported in the last 10 years.

The minimum export being 203,900 Eng: tons, the ordinary export about 470,000 Eng: tons (average of 1894-96 and 1898-1900), and the maximum export 775,500, the difference is about 300,000 tons between the maximum and the average for ordinary years and 570,000 tons between the maximum and the minimum or when the figures for 1893 are to be reduced by 100,000 tons, about 200,000 and 470,000 tons.

The average price of export-rice may be put for the last 4 years (1898-1901) at $ 3.20 per picul (according to the figures for the quantity and the value of the exported rice, as mentioned in the Custom house returns of 1898-1901), or ticals 90 per Eng: ton, so that the difference in the quantity of rice exported between an ordinary and the most favourable year represents a value of 27 millions of ticals and the difference between the minimum and maximum of the quantity exported amounts to the value of 51½ millions of ticals (or 18 millions and 42½ millions of ticals in the case the exported quantity for 1893 is to be reduced by 100,000 tons).

Every one acquainted with the agricultural conditions of Siam will agree that the loss of national wealth, expressed by these differences, must be principally imputed to want of sufficient water for the rice crop.

All the officials and cultivators I have questioned about the matter invariably imputed the repeated failure of crop (in many cases people said the crop failed in average once in 3 years or twice in 5 years) to want of sufficient water.

Failure of crop occurs under three different forms namely, at first when arable land is not cultivated in consequence of unfavourable circumstances, secondly when on cultivated fields the plants wither and die without bearing any appreciable crop and thirdly when a plantation bears a smaller crop than could be expected under normal conditions.

The first case occurs when the rains are so late that cultivation begins to be come hopeless for the season; the second case is generally caused by breaks in the rainfall, which are frequent in Lower Siam; the third case is chiefly connected with untimely cessation of the rains and the flooding.

All three forms of failure of crop are common in Siam and often occur to a great extent.

No one, who has seen the effect of irrigation, has any doubt that such a thing as failure of crop practically occurs in regions commanded by a really adequate irrigation and drainage system, as the regular supply of water is equal to cope successfully with all three forms of deficiency of rainfall.

As a general example of the effect of irrigation may be mentioned here some statements about Java, where about 60% of the paddy fields are more or less irrigated and 40% for watersupply depend upon rainfall only.

Over the 12 years period 1885/1896 the average produce of the paddy fields that have yielded crops has been per bouw (7096 M.^{2}):

for the fields more or less irrigated 29·5 picul (of 61·76 K. G.) paddy and
„ „ „ depending upon rain only 19·0 „ „

Moreover on an average during this period the crop has failed totally:

for the fields more or less irrigated at the rate of 4·4% and
„ „ „ depending upon rainfall only, of 14·3% of the extent under cultivation.

It must be taken into consideration that for the greater part of the irrigated fields the supply is precarious and rather irregular and that the average rainfall in the paddy growing regions of Java is about 2 00 M.

A more specified example can be taken from the great residency of Soorabaya, where about half the paddy fields are irrigated and the other half depends upon rainfall only.

The average produce of the fields in this residency that have yielded a crop in the 6 years period 1891-1896 has been per bouw:

for the fields irrigated 38·2 picul paddy and
„ „ „ depending upon rainfall only 16·6 picul.

Moreover on an average over this period the crop has failed totally:

for the fields irrigated at the rate of 0.9% and
„ „ „ depending upon rainfall only, of 19·8% of the extent under cultivation.

In the residency of Soorabaya the water supply of the irrigated fields is far superior to the supply of the irrigated fields of Java in general; on the other hand the average rainfall, (about 1·70 M.) is considerably less than the general average rainfall of the paddy-growing districts of Java.

The statements regarding the average crops are based on the results of the annual harvest-weighing-experiments, made for statistical purposes and landtax assessment, in great numbers all over the country, (published in the *Koloniale Verslagen*). The figures mean dry paddy in the ears.

The effect of adequate irrigation is especially well exemplified by two neighbouring provinces in the residency of Soorabaya in Java: The province of Sidoardyo, in which are 44,000 bouws of paddy land (1 bouw=7096 M.^{2}=4$^7/_{16}$ rais) is well irrigated by the Brantas delta works. The province of Sidayo, with 40,000 bouws, has no irrigation or drainage works. In the former province the failure of the rice crop in the most unfavourable year did not reach 0·1% of the total; and in the latter the average of failure in the period 1889/1898 was 34%; but in 1896 67% of the crop failed totally.

In the former province the average of the successful crop per unity of extent is nearly three times greater and moreover of much better quality than in the later. In the former the land tax *paid* is 12 guilders per bouw, in the latter less than 3 guilders. (The assessment in the latter is 4·40 guilders, but an average of 34% is written off for failure of crop).

Besides the loss of their crop the cultivators of Lower Siam meet with other losses connected with the present system. Firstly they loose much time in waiting for the regular rainfall, to begin to till their fields and secondly often the new sown paddy is lost, frequently even twice in one season, by periods of drought following short rainy periods or by untimely high water.

Loss of new sown paddy occurs so often that a great deal of cultivators reckon as a rule on sowing twice, which causes a loss for seed grain only, valued at about 3/4 ticals per rai.

Available time for cultivation; quality and quantity of crop.

2. Secondly one of the principal advantages, resulting from an adequate irrigation system, would be that the total space of time available for cultivation of the main crop, rice, would be prolonged greatly,

Under the present conditions, in ordinary years, according to the rainfall statistics, May is the first month in which any considerable quantity of rain falls and October the last. It is in general practically impossible for the cultivators to work their fields before the soil is soaked thoroughly by rain, the clayey soil being too hard and stiff, to be worked dry. In the period of 6 months (May-October) of which the first month is almost always at the best only half available, the fields must grow wet and soft, must be ploughed and harrowed, the seed has to be sown, the seedlings transplanted and the crop must grow and mature.

In the lowest strips of land, between the main rivers, to which I often have referred, in consequence of the flooding the available time is longer by at least a month or even a month and a half to two months, when the high floods in the rivers continue very long.

To lengthen somewhat the available time, principally in order to plant and to ripen the crop, generally under present conditions a great part of the people are obliged to take to scooping or pumping water from the klongs on the fields; but as has been said before, in this way they can only provide a poor supply for a small part of the fields in the immediate vicinity of the klongs, and the time spent on this scooping or pumping is deducted from the time available for reaping and planting.

When they take to scooping on behalf of their nursery beds, as also very often occurs, then the time and labour spent on this work is greatly prejudicial to the labouring of the fields.

Still another method of lengthening the available time specially for reaping, is to commence to cut the paddy when yet unripe and to go on cutting when over ripe.

The necessity of employing these methods to lengthen the available time for agricultural operations must of course have a very unfavourable influence on the quality as well as on the quantity of the crop.

Moreover in years of very scanty rainfall and early fall of the rivers, people not only get a small and bad crop, but besides in general they experience the greatest trouble in reaping what crop they obtain.

In such years, in the higher tracts the greatest part of the paddy generally is too young to run to seed, before the rains have ceased and the rivers subside, and dies in consequence of drought, without giving any crop; in the lower tracts, however, the water falls slower, and there the greatest part of the crop does not quite fail, but when the water falls, ripens all at once and for the most part, of course, very prematurely, which causes the crop to be small and of bad quality.

In such cases people must try to reap in a couple of weeks what they intended to do in at least a couple of months, and quite unexpectedly hands fall short everywhere in the lower tracts; in consequence the crop already bad, grows still worse.

As a natural consequence of the above circumstances all the agricultural work is done in a hurry. The cultivators, after waiting weeks in forced idleness for the rains, work the soil very superficially and even this superficial work is often still very difficult, as the soil is stiff and clayey and it is not always possible to wait till the ground is thoroughly soaked.

Sowing and transplanting is conducted with the same speed, care being bestowed on the work, of course, in reverse proportion to the haste. The weeds even seem inspired by the urgency of speed, their roots and sprouts being little molested by the superficial labouring of the soil, whilst no flooding checks many species which, at least if cut, could not withstand inundation; they try to outgrow the paddy and often succeed in doing so. To cope with the weeds causes the people a great deal of extra labour and moreover these weeds damage the crop greatly both in quality and in quantity.

In connection with the exent of paddy fields worked by the cultivators, the space of time of 5 to 6 months available in normal years for the cultivation of the bulk of the fields, enables them only to plant these kinds of paddy, which become ripe in a period of 3 to 4½ months *(kao bao)* and these even often can not obtain their full requirements with regard to time and water.

Now these kinds moreover, even when fully developed, neither give the most valuable rice nor the greatest crop. The more slow growing kinds *(kao nak)*, that require 5 to 6½ months to ripen, are in general considered as being greatly preferable in both respects, at least when they are not impeded in their growth, by want of water for instance, as in Siam generally is the case.

When however in Lower Siam the cultivators plant these kinds, the lack of water often causes the crop to be poorer in quality and quantity than that of the fast growing kinds.

It is only in the lower strips of land, frequently referred to, midway between the main rivers, that cultivation of the slower growing kinds appears to be possible; and in these parts the conditions with regard to labouring of the soil, also are much more favourable, whilst the same is the case with coping with the weeds. because a great deal of the weeds cannot stand inundation and die if cut under water.

As I must infer from my inquiries, in these lower parts people indeed get in general, besides a greater crop, a considerably higher price for their paddy than in the more elevated tracts.

Deterioration of Siamese rice.

Complaints often have been made by the traders, as for instance was stated in the last British Consular Report about the Bangkok trade, that the quality of the Siamese rice brought to the market, is steadilly deteriorating, which the report imputes to want of care in the selection of the seed-grain and in cleaning and preserving the grain, due principally to scarcity of labour:

These causes of course will always have had a considerable influence on the quality of the Siamese rice in general, as agricultural methods are primitive in Lower Siam; but it seems rather unacceptable that they could act to deteriorate the quality, because there seems to be no reason to admit that labour is growing more scarce and the cultivators attend less to their work now, than they formerly used to do.

The contrary is most likely more probable, because the improvements introduced in civil and financial administration, police and justice and the abolishment of corvée and bondservice must have contributed greatly to the general peace and security and to liberty of action of the people, which consequently will have acted as an encouragement to their zeal and industry.

That this is really the case is proved by the progress of foreign trade.

The imports have increased from $ 10,872,016 in 1888, the first year for which regular records are available, to $ 29,520,730 in 1901; the exports from $ 16,342,026 in 1888 to $ 46,828,791; and the total foreign trade from $ 27,214,042 to $ 76,349,521. Even when keeping account with the fall of silver currency * and with the fact that 1901 was a prosperous year (which however 1888 was also as the statistics of rice export [see page 28] show most evidently), the increase is exceedingly great and cannot but indicate a degree of progress, which it would be difficult to reconcile with decreasing care and industry of the people in their principal means of subsistence, the rice cultivation.

Decrease of hands too is not acceptable, though the sanitary conditions of the people are bad indeed in Lower Siam, because scarcely any woman lives single in Siam, families seem very large in general and everywhere in the country the villages are swarming with children; over and above this, the population is augmented annually by a considerable immigration of Chinese.

The causes of the deterioration of the quality of Siamese rice, in all probabitity, must be looked for in another direction.

Improved security of person and property, enhanced liberty of action and increase of population have caused people to open up new arable fields to of steadily increasing extent, ** but the most suitable tracts, specially with regard to water supply, fertility and transport facilities, being previously already occupied, people have had to content themselves with less favourably situated fields, which in connection herewith yield a poorer crop, both in quality and quantity; this will be one of the causes of the deterioration of Siamese paddy.

A second cause can be traced to the neglect to of up-keep of the klongs, in consequence whereof the watersupply has grown worse and the crop of the lands long under cultivation will have deteriorated. These klongs, as was explained, are constructed without any headsluices to obstruct the entrance of sand and heavy silt, and with their slow current they have a strong tendency to silt up. The abolition of the corvée and the attention paid to reforms in other directions, may have been one of the principal causes of this neglect.

A third cause may be sought in rainfall having decreased and grown more irregular, and the duration of the time of high river level having grown shorter in consequence of progressive devastation of forests, which is stated (see in Mr. Warington Smyth's book "*Notes of a journey on the upper Mekong p. 25*) to be the case in the hill regions of the upper Menam basin, principally in connection with the necessity of frequent changing of the fields for hill rice cultivation.

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* The average price of silver in London was $42\frac{7}{8}$*d.* per std.ounce in 1888 and $27\frac{3}{16}$*d.* in 1901.

** The amount of the paddy landtax was in the year 112 (1893/94), a very prosperous year, Tic. 1.357.861.43 and in the year 120 Tic. 2.914.389.—.The assessment per unity of extent in both years was the same.

It appears to be a current opinion in Siam that rainfall has been decreasing both in the Upper and in the Lower Menam Valley. Decrease of rainfall, of course, tends to prejudice the development of the crop and will besides induce people to reap unripe and overripe paddy.

A fourth cause may be that, in consequence of agricultural improvement in other rice growing countries, while the quality is deteriorating in Siam, the demands of the trade with regard to quality appear to be enhanced.

A fifth cause may be that increase of the wants of the country people for things they have to buy compells them to sell an increased percentage of the crop, including paddy of poorer quality, which they otherwise would have kept for their own use. Besides for the same reason, in some cases people may have taken up more land than they could work satisfactorily under present circumstances, which of course also will be damaging to the quality of the crop.

Last though not least, the fact that during many decades a continually increasing quantity of rice has been exported, will have deprived the soil of a great part of its fertilising substances, which are not in any way replenished by means of manure or by deposition of silt in any important quantity. This process continues and will have a prejudicial influence on the crop.

The fact in question is most likely due to all the above mentioned causes acting together; but however this may be, there is no doubt that by removing the principal impediments to improvement of agriculture, namely, the want of water and, in connection therewith, of sufficient time for proper tillage of the fields and for the requirements of full growth and ripening of the rice crop in general, and of the better kinds of paddy in particular, further deterioration of the Siam rice could not only be checked, but on the contrary, the quality could be much improved.

Under present circumstances the conditions of growth for the crop appear to have a positive tendency continually to grow worse. The plants adapt themselves to this alteration of circumstances, the rice plants specially having a very prompt and complete faculty of adaptation, so that when the conditions are altered to the worse even the best kinds of paddy will deteriorate quickly. On the contrary, if conditions are changing to the better, consequently the paddy also will improve. By importing seed of kinds of paddy that are already adapted to better circumstances, the process of adaptation and improvement of the local seed can be omitted; but introducing better seed without improvement of the conditions of growth cannot but prove deceptive.

Better growth of the crop and cultivation of the better kinds of rice would however not only tend to improve the quality of the rice, but in consequence of the more favourable circumstances, the average quantity of the crop also can be expected to rise considerably above the best average quantity under present conditions.

Available time for cultivation continuation.)

It will easily be seen from what follows, that an adequate irrigation system would improve greatly the conditions of paddy growing by causing a great prolongation of the space of time available for cultivation.

The quantity of water available for irrigation in the dry season and in the very beginning of the rainy season would enable the cultivators, if required, to prepare and sow their nurseries far earlier than under present conditions, when it is necessary to wait, until the rains have soaked the soil sufficiently to make this possible, and are regular enough to make it advisible, with a fair chance of success.

Owing to a fortunate peculiarity of many kinds of Siamese paddy, the seedlings may be still transplanted even when one meter high; therefore no considerable difficulty will be experienced due to the uncertainty of the rise of the river and of the amount of water that will be available to saturate and work the fields, after the nurseries have been prepared.

This peculiarity of these kinds of paddy is an interesting example of the plants adapting themselves to the conditions they have to deal with, and this and still more the floating paddy, are most remarkable agricultural achievements.

As is shown by the already mentioned gauge observations at lock Chulalongkorn from 1896 till now, a couple of weeks before the rains begin to fall fairly regularly in the lower plains, the discharge of the great Menam, and also of the other rivers, begins to rise. Most likely nearly a month, but certainly more than half a month before the time the fields under the present conditions are soaked sufficiently to be worked, the discharge of the rivers will be sufficient to meet the full momentary want of water supply to soak the fields thoroughly, in proportion as the cultivators are able to labour them.

When the rains in the lower plains cease at the end of October, there is still a period of two months and a half during which the great Menam and probably also the other main rivers have a sufficient discharge for all the then wants of the rice crop. Under present conditions in ordinary years only the lowest strips of land midway between the main rivers can profit for a period of about a month or so of the high floodlevel of the rivers, because generally at the commencement of December the high floods have already subsided so much as to be on longer of real profit, even for the lowes fields.

It is therefore certainly no exaggeration to expect that by an adequate irrigation system, the time available in ordinary years for the cultivation of the principal crop, will at least be prolonged by two months and a half as far as regards the bulk of the fields that practically depend upon the rainfall only, and one month and a half for the now most favourably situated small strips of land midway between the main rivers.

Besides increasing the available time for the cultivation, regular supply of water will enable people to have the soil thoroughly soaked, before they commence to work it, which will facilitate and accelerate working the fields and coping with the weeds, and therefore even involuntarily improve the labouring and weeding.

The consequence of all this must be: more favourable conditions for ricegrowing in general, and better cultivation of better kinds of paddy in particular; thus improvement of the quality and quantity of the crop.

The importance of improvement of quality may be inferred from the fact that in Java in general the price of imported Siamese rice is 4½ to 5 guilders per picul, whilst the good quality Java rice costs 6½ to 7 guilders a picul, and the very best Java rice (Indramayoe) often fetches 8 to 9 guilders and more for export to Europe. *

The market value of Siam rice in general is now already higher than that of Rangoon and Saigon rice, which is encouraging and seems greatly in favour of the Siamese cultivator and Siamese soil, the rainfall being in Burmah and Cochin China much more favourable for rice growing than in Siam.

A less abundant rainfall in all probability is no longer a disadvantage with regard to rice growing, if only the water required is supplied artificially, because then the sky is less clouded and sunshine more profuse.

Extension of cultivated area.

3. A third considerable advantage connected with an adequate irrigation system would be, that the extent of land tillable by the same hands will increase considerably, in consequence of the work being easier when the soil can always be saturated and inundated at will and of the entire space of time available for agricultural operations being prolonged by at least two months and a half for the ordinary fields and one month and half for the small part of most favourably situated lands.

In the present conditions the cultivators often lose their time by waiting for weeks till rain has fallen sufficiently and is regular enough to enable them to begin the work. Then they must hurry on as much as possible in labouring the fields, in sowing and in planting their paddy, to have the crop in a sufficient state of ripeness when the rains cease and, as far as regards the small strips of low land midway between the main rivers, when the rivers subside.

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* The rice of Indramayoe and of Kandanghauer was sold at Batavia (in lots of about 40.000 picul) in 1898 respectively for 8.54 and 8.88 and in 1899 for 8·61 and 9·60 guilders per picul. (Reports Chamber of Commerce, Batavia).

The want of inundation during the labouring of the fields, causes the weeds to flourish instead of dying and this afterwards entails a great deal of labour, frequently with little result, in the endeavour to prevent them overwhelming the crop. With inundation, most weeds die, especially when cut under water.

To lengthen somewhat the time available for the ripening of the crop when the rivers are falling, most of the cultivators are obliged to take to scooping and pumping. This operation produces only small results and occupies a great deal of time, which is deducted from the time, available for harvesting.

When people are obliged to take to scooping or pumping to save their nurseries, as is often the case, the time spent on this is deducted from the time available for working the fields.

The extent of land which can be cultivated by one person is limited by the time disposable for the agricultural work, and in particular by the time available for reaping, which is the most laborious operation in rice growing.

The labouring of the fields and the reaping of the crop proceed gradually, the latter due partly to the fields being planted and sown gradually and partly to the paddy planted requiring different periods of time for ripening. By this means the cultivators strive to arrange matters so, that during the whole period of harvesting there shall always be enough of their crop ready for the reaping, as can be managed by the hands available. But untimely cessation of the rains and fall of the rivers, often spoil these calculations and cause the crop to ripen all at once (or to fail).

The extent of the farms therefore as a rule is limited by the amount of land that can be harvested by the hands available within the harvest period.

The hands available consist in general of the farmer and his family, to which are sometimes added one or two servants hired for the season.

The time of reaping begins when the fastest ripening kind of paddy is mature and lasts until after the ceasing of rainfall or flooding, when paddy can no longer ripen.

In many cases, as may be mentioned here again, people try to prolong the period of reaping by beginning to cut still unripe and ending by cutting over-ripe paddy, both of which tend greatly to spoil the quality of the whole crop.

In the small strips of land between the main rivers, where after the rains have ceased, flooding still continues for some weeks and the hands are not so frequently withdrawn from harvest work for scooping, the reaping period is considerably longer than in the higher lands, that are only flooded for a short period during the heavy rains, when water is least required, or even are not flooded at all.

In general the extent of land worked by a single family in these small strips between the main rivers appears to be much greater than elsewhere.

From numerous inquiries I made into this matter, I infer that an average farmers family consists of husband, wife, 2 or 3 half grown up and a couple of young children (adult children are scarcely ever seen in Siamese farmers families, they are either serving their term as soldiers or are in the priesthood or already married and established themselves), and that in the lowest strips of land between the main rivers, such families as a rule work no less then 80 to 100 rais and sometimes 200 and more rais of paddy fields, without servants or labourers ; whilst in the higher regions, where no flooding occurs or flooding ceases nearly together with rainfall, very few families appear to work more than 30 to 40 rais and 60 rais seemed to be the very maximum.

Specially in the last mentioned tracts, uncultivated land is over-abundant; but always, when asked why people did not cultivate more land and work as large an extent as in the lowest reaches along the klongs, they replied that they could not work such an extent, because they had more trouble with the weeds and a much shorter space of time for reaping their crop.

In the lower parts of the Klong Rangsit region, where by the effect of the retaining-locks, the flooding lasts longer than anywhere else in Lower Siam, the extent of land generally worked by a single family often appears to be still greater than in the most favourable parts of the other klongs.

From these facts may be inferred that an adequate irrigation system, by which the time available for cultivation will be at least prolonged by two months and a half for the bulk of the fields, by which working the fields and coping with the weeds will be much easier because the soil always can be thoroughly soaked before being worked, and by which the fields can be inundated at will, would enable the cultivators to work at least double the extent of land that they can work now in the more elevated tracts.

For a country like Lower Siam, where uncultivated land is abundant, this result of irrigation gives an enormous advantage, which in densely populated and entirely cultivated regions is of no effect.

A considerable extension of the area under cultivation therefore can be expected, as a consequence of carrying out an adequate irrigation and drainage system, which moreover will render more accessible a good deal of waste land.

By the way I cannot neglect to observe that the ability the Siamese farmers show in cultivating, though the method is rather primitive, such a considerable extent of land (at least some 5 to 10 times greater than for instance is usually the case in Java and India), is quite remarkable.

The cultivation of such extents of field would be a serious matter, even for the hard toiling farmers of Western Europe, where however cultivation requires much more labour than rice growing in Siam.

Silt on the fields.

4. The fourth principal advantage of an adequate irrigation system will be that by means of the current in the main canals, the distributaries and the sub-distributaries a great quantity of silt will be carried to the fields.

It has already been pointed out that under present condition, scarcely any of the silt of the rivers comes to the fields. The fact was also referred to that it is quite certain that the silt of the great Menam and the Meklong rivers is of great fertilizing power. Wherever I saw the water from the rivers or from the running klongs, which draw their water from the rivers, spreading over the paddy fields, this was most obvious, from the fact that round the spot where the water entered into the field and therefore the greatest part of the silt is deposited, the growth of the plants was extremely luxuriant, compared with the rest of the field, and still more compared with neighbouring fields at a greater distance from the river.

The water of the Brantas river, one of the principal rivers of Java, shows the same effect to about a similar degree and scientific experiments on the quantity of available nitrogen, potassium and phosphoric acid contained in the silt of irrigation canals fed by that river, have shown that its manuring value is half as great as that of stable manure of cattle.

The manuring value of the silt deposited on one bouw (7096 M.^{2}) of paddy land irrigated from the mentioned river in one rainy season can be estimated, only with regard to the available nitrogen (the nutritious matter generally in minimum in the irrigated plains of Java) on about 16 guilders per bouw i. e. about 5 ticals per rai. *

One of the principles of adequate irrigation is, that the water on the fields is never stagnant but always flowing, being the superfluous water supplied by irrigation or rainfall, drained off in drains and canals destined for the purpose.

The aim of this system of continual supply and flow off, to as great a quantity as possible, is to prevent stagnation of the water on the fields, which is considered to be very disadvantageous to the prosperous growth of plants, and at the same time to increase as much as possible the quantity of silt carried to the fields and to distribute it as proportionately as possible.

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* *See next page.*

As the water of the great Menam and other available rivers contains a great quantity of fine silt that can be easily carried on by any current, and as the fertilizing value of this silt is indisputable, therefore the quality and quantity of the crops could be improved greatly by carrying this fertilizing silt to the fields by irrigation.

In all probability, a proper supply and distribution of this fertilizing silt to the fields will form the most effective and least expensive method of compensating for the damage, inflicted on the soil by the continued export of agricultural produce on a large scale.

This function of the system is of course closely connected with and greatly depends on adequate drainage works.

Paddy na muang.

5. Besides the above, there is still another reason, connected especially with adequate drainage, from which an increase of the quantity as well an improvement of the quality of the crop may be anticipated.

Some parts of the low tracts of land lying between main rivers are situated comparatively very low. The existing canals, which run through these parts are all, except the klong Rangsit, in open communication with the main rivers, and so tend to raise the floodlevel on the lowest fields to the same level as the rivers have at the locality where the klongs join them.

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* The results of the investigations made by the Agricultural Station at Passoeroean (Java) are as follows:—

Two series of samples (A. & B.) taken daily, during a period of 65 days, at two different places from the Brantas delta canals (irrigated area 33.000 A. H.), held on an average 408 m. G. (samples A.) and 422 m. G. (samples B.) silt, dried at a temperature of 125° C.

On an average the silt contained:—

		Phosporic acid.	*Potassium.*	*Available Nitrogen.*
Samples	A.	0.66 %	0·60 %	0·27 %
,,	B.	0·35 ,,	0·43 ,,	0·25 ,,

A water supply of 1.5 L. per bouw and per sec., as is usual for the paddy fields commanded by these canals, amounts in a period of 120 days to 15,552 M.^{3} and carries to the fields, according to the least favourable series of samples B., a quantity of 6,563 K. G. dry silt containing 22·97 K. G. Phosphorie acid, 28·22 K. G. Potassium and 16·41 K. G. available Nitrogen; the value of the available Nitrogen, when applied to the field, being on an average about 16 guilders as mentioned above.

Investigation of the quantity and quality of the silt held by the water of some irrigation canals in other regions have shown similar results.

Prof. Adolf Mayer, in his *Handbuch der Agriculturchemie*, states as average figures for stable manure of cattle: Phosphoric acid 0.27% Potassium 0.67%, and available Nitrogen 0·54%

The water in the rivers in ordinary years rises to about the ground level of the banks, and as the klongs generally run about transverse to the main direction of the rivers, the flooding in the lowest parts naturally must become very deep in consequence of the slope of the ground in the direction of the klongs. Moreover the dykes of excavated earth alongs the klongs add no small part to the natural obstructions against drainage and so at the time the water in the rivers and in the klongs is growing to the highest level and rainfall is still heavy, the very lowest parts often become flooded for some time as deep as 2 M. and more. In these conditions only na muang paddy can be cultivated. *

The na muang or floating paddy has assimilated its character most wonderfully to the hydrographical conditions of its surroundings, so that even the

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* *Kao Na Muang*, floating paddy or field-rice, is a variety of rice, peculiar to Siam, and imported into Cambodja and Cochin China, which grows especially on deep inundated fields and has adapted its character in a most remarkable way to the conditions of the locality.

After a very superficial labouring of the soil, this rice is sown broadcast on the fields, which in general are not parcelled out by small imbankments, as usually is the case with paddy fields.

Sometimes, if there is already too much water on the fields for sowing, the grains are planted in small holes made by pointed sticks, and afterward filled up by the feet of the planter.

The paddy then sprouts and grows quickly; during the period of vigorous growth, a growth of even 5 c. m. a day is often stated. If now the water does not rise quicker than the paddy can grow, then the plant may bear any inundation of even to 3 or 4 M., the stalks growing so long that the top of the plants and the leaves are always above the water.

The stalks, under the influence of wind, current and their own weight, take a slanting position, the top being bent up again however. When the flood is very deep and the stalks become very slanting, then the plants can grow to an enormous length, 6 to 8 M. being no exception. When the water does not rise high, the plants grow like a vigorous kind of common paddy.

Another peculiarity of the plants is that new systems of roots and also new stalks sprout from the nodes. These roots however do not reach the ground but feed upon the water only.

With one particular kind, growing in very deep water, the original stalk and roots become very slightly developped, but are preserved merely as a kind of cable and anchor by which the plant is retained on the spot. whilst the nutrition-functions almost entirely depend upon the root systems that sprout from the nodes and feed upon the water only.

These facts, it may be observed by the way, are of great importance as to the function of the water with regard to paddy growing and confirm the opinion that paddy for its nutrition and growth does not depend in such a degree as other cerials, upon the soil and its contents of nutritious substances and humus, as an intermediary, but can utilize directly the substances contained in the water. They also contribute to explain how it is possible that well watered fields year after year can yield a good paddy crop without showing visible signs of deterioration.

The paddy na muang is generally weeded, and if the water has not yet subsided when the crop is ripe, also harvested in boats. In the last case fishes often consume a good deal of the crop.

There are quickly and slowly ripening kinds of paddy na muang and also glutinous kinds.

The crop often fails partly or totally, in consequence of the water rising too fast, and submerging the plants, or falling before the plants have formed their ears and are able to ripen.

The crop, even under favourable circumstances, is considerable smaller and of poorer quality than that of common rice.

highest flood will not injure it, provided only that the high floods do not come when the plants are too young or that the water does not rise too fast.

One of these things however, or both of them, are likely to occur rather frequently and cause a good deal of the na muang crop to be lost. People told me in many tracts they estimated one crop lost to two successful crops.

In order to diminish the chance of failure of crop, therefore the paddy na muang fields must be sown as early as possible and in as short as possible a space of time.

Withering and dying of new sown paddy then, however occurs very often in the na muang tracts.

Some times even it is not possible to sow the paddy on the lowest tracts, because the time between the soil being soaked by rainfall and fit for labouring and being already inundated by drainage water from higher tracts is too short to allow any cultivation.

On the other hand, when the water has gone down the crop must have grown to a sufficient state of ripeness to be able to become mature; the uncertainty about the subsiding of the water therefore enforces people to take to comparatively early ripening kinds of paddy na muang.

Owing to these two causes the extent of land that can be cultivated by one person with paddy na muang is limited, so as not to be much larger than for fields depending upon the rainfall only.

Moreover any irregularity of the rise or fall or the water, while not quite spoiling the plants will soon impede the prosperous growth and damage the quality and quantity of the crop.

At the best the paddy na muang, compared with paddy na suan, (common rice) gives a light crop of an inferior sort of rice.

According to the information I obtained, a crop of $^2/_3$ of the quantity of paddy na suan may be taken as a fair average and the price of na muang rice is about $^3/_4$ of the price of good na suan rice in similar conditions.

By an adequate system of irrigation and drainage the high flooding of the lowest parts would be obviated and all superfluous water drained off, so that the conditions of the present na muang fields would become the same as the future condition of the present na suan fields, and this will, for the localities concerned, cause the same advantages, but to a higher degree, as already mentioned, viz:

1. Protection against loss of crops, by timely supply of water;
2. Increase of quantity and improvement of quality of crop, by planting better

yielding and more valuable kinds of paddy, in consequence of the increase of the time available for cultivation ;

3 Extention of the lots that can be cultivated by one person, in consequence of lengthening of the time available for reaping and of facilitating the labouring of the soil and

4 Fertilization of the soil, by systemetically carrying silt to the fields.

Villages, Gardens and Orchards.

6. Another advantage of adequate irrigation, depending also principally upon the drainage system connected herewith, is that people will be enabled to prevent the inundation of their villages and gardens, by draining them into the drainage canals.

When the soil around their houses is not subjected to inundation, people will be able to plant fruit trees and cultivate other garden produce, which in the present circumstances is impossible or hardly possible in a great part of the country, because the young plants cannot withstand inundation, even for a period of some days.

It is a particular feature of Lower Siam, that trees, and specially fruit trees, are very scarce, except in the highest tracts along the rivers, and fruits are rare and high in price, which is due to the above circumstances.

In some parts, for instance in the vicinity of Pakprio, even bamboo, that stands flooding better, does not grow. The high banks of the rivers and the dykes of excavated earth along the klongs, at present are the only localities where trees in any important number are found in the lower provinces of Siam.

Clumps of fruit trees in the villages all over the country would not only contribute greatly to the profit and the enjoyment of the people, but are considered also to be of favourable influence on climate and rainfall.

The conditions of cattle breeding, with regard to treatment and for keeping manure, will become much more favourable also.

Cattle breeding is of great importance for Siam, both with regard to the use of cattle for agricultural purposes, and for exports; cattle being a considerable heading of the export trade (about $ 1/2 million a year), which shows however a tendency to decrease.

Want of proper fodder and of good drinking water in the dry season and want of dry ground in many localities in the height of the floodseason, under present conditions are the principal impediments of the extension of cattle breeding in Lower Siam, and in particular of improvement of the breeds, which are not of a high standard. Better breeds have higher requirements and would not stand the period of scarcity of fodder and bad water, to which annually even a good many of the native cattle succumb.

By proper drainage, the aspect of the villages would become quite changed and embellished and the inland people would gain greatly in domestic accomodation. The habit prevailing in many localities of removing in the dry season from the fields to the river banks or to boats, would certainly disappear in consequence of the more habitable character the villages soon would assume, the more because perennial irrigation canals also will provide tbe whole area concerned the whole year over with fresh drinking water.

Drinking and flushing water.

7. The last mentioned circumstance constitutes a further advantage connected with an adequate irrigation system, by which a great part of the population of Lower Siam would be greatly benefitted.

Under the present conditions, when the rivers subside, the klongs in the higher regions of the Lower Menam Valley gradually grow dry and in the lower provinces the water of the lower parts of the rivers and of nearly all the klongs grows salt or brackish and quite undrinkable and remains so for a period of about 3 to 6 months. In the klongs which are not quite dry or brackish in the dry season, the stagnant water gradually becomes bitter, or sour as people say, by the ground water draining off into the canals. The ground water contains a good deal of magnesia and alum derived from the marine sub-soil, and is very hard and quite undrinkable. Wells therefore have generally also only bitter or sour water in the dry season.

The consequence of these circumstances is, that a great part of the year people use all kinds of bad and dirty water which they have still at hand, and so try to get on as long as possible. In all probability this causes a good deal of disease for men as well as for cattle; enteric diseases being very common with men and live stock in the dry season.

At the time the klongs are quite dry or the water they contain is too brackish, bitter or sour, people are obliged to fetch drinking water for themselves and their cattle, by boats or bullock carts, from the higher parts of the rivers, which often takes a journey of some days. The price those, who are not in the position to fetch water themselves, have to pay for fresh water, varies from 1 to 10 ticals a $M.^3$.

To fetch drinking water during three to six months every year causes a great deal of trouble and work to men and cattle, which could be spent in a more profitable way, if fresh and comparatively pure water was distributed all over the country throughout the whole year, by means of perennial irrigation canals.

This certainly would constitute the greatest and most general improvement ever achievable, of the sanitary condition of the whole population and live stock of the lower provinces of Siam, where at present enteric diseases both of men and cattle are frequent, whilst up country they are rare.

It may be set forth here that this advantage of perennial supply, though not the most important from a financial and economical point of view, certainly would form the most urgent of all improvements to be brought about by an irrigation and drainage system.

It may be especially pointed out that a continuous supply of fresh water would be also a great advantage to Bangkok and its suburbs, and would probably prevent epidemic disease to a great extent, though it would not by any means render superfluous an aqueduct system for purified potable water.

The cost and the working expenses of waterworks in that sense, however would be much reduced, as the water could be taken from the irrigation canals and thus the source of supply would be brought near to hand. *

Further, water could, as a matter of course, be drawn from the canals to scour into the river the dirt out of the drains of the capital. The requirements of irrigation will demand a waterlevel in the canals quite sufficient for the purpose of flushing the drains of the town all the year through.

It may be worth while to set forth that, however great the importance of providing drinking and flushing water for Bangkok may be, the whole, (probably 10 times more numerous) population of the entire lower provinces find themselves in much worse conditions than the Bangkok people, with regard to drinking water in the dry season and certainly suffer more and have a greater loss of life and property on that account.

Dry season crops.

8. Another very important advantage of a perennial irrigation system is that in the dry season a considerable quantity of water will always be available for agricultural purposes.

For a second crop of rice this quantity would not be sufficient, except for a small part of the total area under irrigation.

A second rice crop however would not at all be advisable, because it would most likely tend to fatigue the soil, with regard to rice and so damage greatly the crop of the proper paddy growing season; moreover it would enhance the danger of diseases and blights of plants and crops, by breeding and continually keeping alive, as it were, the germs of disease, which else would probably die in the dry season, from want of suitable conditions of living.

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* In all probabity, under present conditions, the only way practically available to provide Bangkok with potable water is to derive it from the great Menam, at a locality where the river never becomes brackish.

According to a provisional estimate of the Chief Engineer of the Local Sanitary Department, the cost of waterworks with a capacity of 20,000 M^3 per day (or 230 L. p. sec.) and offtake at Chiengrak, 30 K. M. above Bangkok, would be about 5½ mill. ticals, of which amount 2¾ million on account of the pipe conduct of 30 K.M. and pumping station, which could be omitted, if the water could be taken from a canal with a steady current near Bangkok.

If the irrigation scheme is carried out, the Menam will be tapped of perhaps 9/10 of its water and grow brackish further upstream than at present. A pumping station then for its supply would be obliged to have recourse to a neighbouring branch of the irrigation system.

A second crop of rice, in other countries also, only is possible in very rare cases and generally gives poor results, so that often one proper rice crop in the rainy season has a higher value than a double crop.

A second crop is often talked of, mostly by people who are little aware of the difference between a good and a bad crop, but only count a crop as a crop.

Instead of rice in the dry season, it would however be possible to cultivate on the irrigated fields several other kinds of crop, which require no more than about one fourth or one fifth of the quantity of water required for rice and which would form a rotation with rice cultivation, and so not tend to deteriorate the soil, but some crops, such as all kinds of beans, peas, and other leguminosae, on the contrary even will ameliorate it greatly, by increasing the nitrogenous substances of the soil. Most of these crops moreover water mature quickly and have a considerable value.

According to numerous and very careful experiments made in Java, irrigation of sugar cane, maize, etc. in the dry season requires on an average a quantity of 0.30 to 0·45 L. of water per sec. and per H. A.

As suitable for second crop in the dry season may be mentioned maize, beans, pease, cotton, tobacco, earthnuts, indigo, casada, vegetables, etc., all which plants in tropical countries require irrigation to yield a paying crop, however not in the way of continual inundation like rice, but only as a moistening of the soil from time to time by scooping or soaking.

The quantity of water available in the dry season appears to be sufficient for the requirements of these kinds of crop to the whole present extent of the cultivated area under command.

Most of these products, specially cotton, tobacco, indigo, earthnuts and cassada (tapioca) are articles of trade as well as of local use.

Cotton growing on a large scale would probably be precursory to cotton manufactory, cotton goods being the chief article of import of Siam.

Tobacco is also imported in considerable quantities and no doubt could easily find a local market.

For cotton and tobacco growing, the conditions appear to be favourable, because as shown by experience, dry weather and profuse sunshine do suit these plants particularly, if only sufficient moistening of the soil is possible.

Sugarcane, now cultivated as a garden plant, could certainly be grown with much success, if the watersupply and drainage could be commanded according to the wants of the cultivation, by an adequate irrigation and drainage system.

Half a century ago there were 30 sugar manufactories in the province of Nakon Chaisi, each working with 200 to 300 Chinese labourers and Siam exported sugar by shiploads, as Sir John Bowring mentions in his book on Siam.

At present sugar is imported in Siam to the value of nearly two millions of ticals and sugar manufacture in Nakon Chaisi has nearly disappeared, principally because the agricultural conditions were too unfavourable to admit of competition with the progress in cultivation of cane and manufacturing of sugar in other countries, and have grown worse by the decrease of the watersupply to the Supan river by the klong Makamtau, in consequence of the silting up of the mouth of that klong.

If however an adequate watersupply and drainage system comes into operation, it may be expected that Siam will soon be able to compete in producing sugar at least for its own consumption.

The cultivation of mulbery shrubs may be mentioned here seperately. On the possibility of these plantations the prospects of extension and improvement of sericulture depend greatly. This possibility is most closely connected with an adequate watersupply in the dry season, because moistening of the soil by fresh water is one of the first requirements for the shrubs to produce a good crop of leaves in that period; whilst in the rainy season adequate drainage is indispensable and flooding disastrous to the plants.

Sometimes people have wondered at rice being almost the exclusive crop in Lower Siam, and all other crops, as maize, cotton, tobacco, etc. as well as the cultivation of trees, being nearly neglected; but in reality this is no surprising fact at all.

In the rainy season the climate is too wet, in connection with the conditions of the soil and the possibilities of drainage in the flat plains, to allow any cultivation, except rice, to succeed in nearly the whole of Lower Siam, though for rice cultivation the rainfall is insufficient. Maize, cotton, tobacco, earthnuts, vegetables etc. require for success a moist soil, but not a continuously soaked soil, to which the air can get no access, and still less do they require flooding.

These plants cannot stand even heavy rainfall. Sugar cane and mulbery shrubs, for instance, stand heavy rainfall very well; when sugar cane is already of a certain height it can stand even flooding for some time too, but mulbery shrubs and also fruit trees are soon badly affected by flooding. The scarcity and high prices of fruits point to the difficulties, fruit tree cultivation has to deal with.

For these reasons all crops, except rice, in Lower Siam are grown on elevated beds, reaching considerably above the high floods, with deep ditches between in which the beds can drain off. This arangement is practically only possible in the high tracts in the vicinity of the main rivers, which are of little value for paddy growing, and even there is very expensive.

Adequate drainage would render possible the growth of sugar cane, mulbery and fruit trees all over Lower Siam; but even then, and on elevated beds, maize, cotton, tobacco, earthnuts, most vegetables etc would fail in the time of heavy rains. In Java it often occurs that even in the dry season these crops are quite spoiled by rain.

Moreover most of the other crops are less valuable than a good rice crop or require much more labour.

Therefore it results from the climate and from the nature of the soil, that as under present conditions in Lower Siam, so even with an adequate irrigation and drainage system, rice will be the predominant crop in the rainy season.

Siam has no reason to complain of this circumstance, as may be inferred at once from the fact that in many countries, for instance in Italy, Spain and in the last years on very extensive scale in the southern parts of the United States the farmers have abandoned cultivation of others cerials and crops for rice-growing, where the climate allows and sufficient supply of irrigation water enables them to do so with success. The only reason thereof is, of course, that rice growing secures them greater profit.

On the other hand in the dry season, without proper moistening, generally the soil is too dry for any successful cultivation; even the most resisting grasses and weeds wither and in many localities the leaves of most trees and even of bamboo shrivel.

Sesame (teelseed) is the only dry season crop grown under present conditions without watering, but only in a few very low places, where the level of the under ground water is least low. The crop appears to be very poor; the export is about 15.000 picul per year only.

Under present conditions, moistening of the soil with fresh water is not possible, except in the vicinity of the higher parts of the main rivers, where the water remains fresh in the dry season.

On the banks of these parts of the rivers formerly a good deal of cotton was grown and moistened by carrying the water from the river up to the fields situated at a higher elevation of many meters. This operation however requires an enormous amount of labour and in later years, as labour has grown dear in Siam and the value of the crop was not so very great, this cultivation has almost been abandoned.

Maize and tobacco growing, to a small extent and for local use, continues however to go on in the dry season at many places on the banks of the rivers.

If fresh water for moistening were available all over the country at the level required, cultivation of cotton, maize, tobacco, beans, earthnuts, casada, vegetables etc, will become easy and profitable and therefore most likely very general. Teelseed cultivation also will become much easier and more profitable, though it is very probable that other crops will prove to pay better.

Special attention may be drawn to the cultivation of grass or foddercrop for cattle on the paddy fields in the dry season, which would be possible all over Lower Siam, if water is rendered available by an adequate irrigation system.

Orchards, which at present are only possible in the high parts near the main rives and now experience great difficulties in the dry season, when the water of the klongs and in the ditches between the beds is brackish, would of course also benefit largely from a regular supply of fresh water in the dry season and of drainage in the rainy season, so that a great extention of this branch of agriculture all over the country may doubtless be expected in the event of the introduction of an adequate irrigation and drainage system.

Navigation. 9. Still another advantage which would accrue from adequate perennial irrigation works is a great improvement in interior navigation.

Scarcely any landroads exist in Lower Siam, and to bring about a road-system under present conditions, moreover, would be rather difficult because the floods, even when lasting only for some days, would annually damage the roads to a great extent unless they were constructed on embankments reaching above highest floodlevel, which however would be extremely expensive. Such being the case, interior navigation and navigation canals are of the highest importance.

Navigation provides the general and almost the only means of transport and communication throughout Lower Siam, in which respect Siam is not so unique as many people imagine, but resembles, for instance, some parts of Holland.

Water transport has the great advantage of being less expensive than any other means of transport and when the waterways are suitably arranged, they enable considerable rapidity of locomotion also.

The advantages of waterways appear to be of such importance in modern competition, that the Royal Prussian Government, perhaps the most active Government in economical matters that exists, though owning itself the whole railway system of the country, is contriving canal schemes on a most extensive scale, to promote cheap transport of bulky produce.

At present in the dry season most klongs are either entirely impassible or are navigable by small or half loaded boats only for a couple of hours per day during high tide.

In case of perennial supply the existing canals would of course have to be improved by excavating them to the required depth and providing them with locks, in order to be able to maintain a regular high level and to prevent the fresh water from running out and the salt water from coming in the canals; then navigation would have no trouble and loss of time by waiting for high tide and sticking in the mud would be avoided, the boats being able to go on, on every hour of the day the whole year over with full load.

The aid of the tidal currents in the klongs, the boatmen will however lose in moving their boats; but compared with the profits in other directions, this is certainly a small loss; the more so, when tow-paths are constructed along the klongs, which can be considered as a matter of course.

The absence of the tidal current at least causes no complaints in the case of the klong Rangsit, which klong is closed by locks, and there is surely no reason to suppose that the traffic in that canal suffers from the absence of the tidal current.

Besides the klongs, many parts of the higher reaches of the great Menam and of the other main rivers also are very shallow in the dry season and produce great difficulty to navigation.

These troubles will be prevented by using, for navigation, the principal supply canals, that will run more or less parallel to the rivers.

Further an adequate irrigation and drainage system will indispensably require a enormons extention of the whole canal system, which in a country like Lower Siam of course will be made fit for boat traffic and so will tend to the advantage of general communication.

That the furtherance of water communication, obtained by bringing about irrigation and drainage works, will be of high importance to the country, will appear from the following considerations.

The rice export from Bangkok in 1901 was 11,466,000 piculs and the export of paddy 41,000 piculs, equivalent to about 28,000 piculs rice (1 pic paddy=$^2/_3$ pic. rice) so that the total equivalent in rice is 11,494,000 piculs.

The quantity of rice transported by the Royal Railway to Bangkok during the Siamese year 120 (1st April 1901-31st March 1902) amounted to 48 metric tons and of paddy 31,850 tons, equivalent to 21,200 tons of rice, so that the total equivalent in rice transported by rail is 351,000 piculs (of 133$^1/_3$ lbs av.) or about 3% of the total rice export.

The rest of the rice and paddy exported, viz: 97 %, must therefore be conveyed to Bangkok by water.

The value of the export trade of Bangkok, exclusive of rice and paddy, in 1901 amounted to $ 9,171,040 and the value of imports to $ 29,115,358.

The total of the exports, excluding rice and paddy, and of the imports was thus about 38 million dollars. Estimated at an average value of $ 200 a ton, this would make a quantity of 190,000 tons of goods.

The total of the traffic to Bangkok by the Royal Railway in the year 120 of all the kinds of goods mentioned in the exports returns, excluding rice and paddy, amounts to about 8,200 tons and the total of the traffic from Bangkok of all the kinds of goods mentioned in the import returns is about 4,000 tons. *

The total of both amounts to about 12,200 tons, *which includes all traffic from and to Bangkok for interior trade in the kinds of goods concerned.* This total makes about 6½ % of the estimated total quantity of 190,000 tons of export goods, excluding rice and paddy, and import goods together, so that at least 93½ % of the traffic in export goods, (excluding rice and paddy), and in import goods, is effected by water.

The great importance of inland water traffic for Siam, as compared with a successful enterprise as the Royal Railway (net earnings 3 % of the outlay) is obvious from the figures mentioned; but over and above their value for the export and the import trade, the waterways in Lower Siam are nearly the only roads for the small local traffic and for general communication, with regard to persons as well as to goods.

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* Abstract from the Traffic Report of the Siamese Royal Railway for the year 120.

Goods despatched from Bangkok station and appearing under import headings.		Goods received at Bangkok station and appearing under export headings, rice and paddy excluded.	
	m. tons.		m. tons.
Cement	30	Gum	45
Cloth	514	Hides and horns	904
Coals	5	Poles, timber	3,809
Earthenware	304	Planks	35
Gunpowder	7	Piece goods	235
Household-goods	33	Resin	191
Matches	240	Sundries	19
Oil	138	Wax	5
Piece goods	1,117	Bullocks	2,920
Steel and Iron	761		
Sugar	45		
Sundries, provisions	708		
Tobacco	69		
Total in tons.	3,971	Total in tons.	8,163

The following returns of observations regarding the boat traffic in some klongs, in April last year undertaken by the Ministry of Agriculture are very interesting.

In klong Tamnern Seduark were counted in five day 3168 boats passing of all kinds; in klong Prawet 2291 boats in five days; in klong San Sep 5302 boats in five days, of which 3595 were small; in klong Rangsit 2978 boats in five days of which 2433 of small size; and in klong Pa Si Cherern 9851 boats in seven days, of which 7830 were small.

A traffic of 1406 boats per day, of which 1119 of small and 286 of big size, as stated in the klong Pa Si Cherern, is most marvellous, being a frequentation of 200 boats per day, already an extraordinary number for the most frequented canals and rivers in Europe.

As an example of one of the most frequented waterways of Europe may be stated here, that during the year 1898 in both directions together 58,546 boats passed the Rhine at the German-Dutch frontier, i. e. on an average 160 per day which, however, are of much greater size then the Siamese big boats. The usual big boats in Lower Siam are about 15 M. long, 4½ M. wide and have about 1¼ M. draught, whilst the very biggest are about 20 M. long, 5½ M. wide and have a draught of about 1¾ M.

Now the principal means of communication, be it landroads, waterways or railways, require, it needs scarcely be said, the constant attention and interest of every Government, as being most valuable agents for the industry of the nation.

Extension, improvement and upkeep of the canal system is inseperably connected with any adequate irrigation and drainage system. In a flat country like Lower Siam where waterways form already the general means of communication, the irrigation and drainage canals as a matter of course will be arranged as navigation canals and therefore produce a great advantage in respect to communication.

Construction of Roads.

10. The last advantage of adequate irrigation and drainage, which I will refer to, is connected with landroads.

Roads are rare in Siam, but in those parts where suitable waterways exist, they are of course not so much needed, since transport by water, as already mentioned, is much less expensive than by any other means of transport and therefore bulky goods, where possible, always will be carried by water.

In conveyance of persons by water the Siamese moreover have such an amount of skill and practice, and boats as means of conveyance are so inexpensive, compared with vehicles and draught animals, that apparently in Lower Siam no frequent road traffic can ever be expected in regions where suitable waterways exist.

However for vicinal communication in towns and villages, for places distant from canals and for administrative and policing purposes, a system of roads will, even in regions crossed by waterways, be of great utility.

Under the present conditions, building as well as maintaining of roads would be excessively expensive in all those regions, which are flooded to a considerable depth, even when only for some days, because, if roads are to be always practicable and not continually damaged, (and if not so they would lose a great deal of their utility in ordinary circumstances), they ought never to be submerged, therefore under present conditions in Lower Siam roads must be made on high enbankments, which are very expensive and moreover very liable to damage.

When this is neglected an annual flooding even for a period of a few days would spoil entirely the roads and make the upkeep almost impossible.

When however, in consequence of adequate irrigation and drainage works, supply and drainage of water can be directed at will for every part of land, then the submerging of roads can be prevented and the difficulties will vanish, by which, at present, construction and upkeep of roads is impeded in the regions concerned.

Moreover the embankments, formed by excavating the new principal irrigation and drainage canals, will at once constitute suitable roads; whilst the embankments of the minor canals and those formed by digging out the existing klongs, at least will be suitable for towing and pedestrian paths, which by gradual enlargements can furnish the base of a system of trunk and minor roads.

Many other favourable consequences of irrigation could still be taken into consideration, for instance: in respect to facilities of fish rearing, by water being at hand throughout the year all over the country; with regard to increase of rainfall by augmentation of the evaporation in the regions concerned; relating to the destruction of many vermin and of fieldmice, which cannot thrive on well-watered grounds; concerning provision of fresh water for industrial purposes, when the rivers are salt etc; but by what has been mentioned above about the advantages of an adequate irrigation and drainage system, with regard to security, quality and quantity of the rice crop, to fertilizing the fields by carrying on silt, to dry season crops of other plantations than rice, to garden cultivation, to provision of fresh drinking water for the whole Lower Menam Valley and scouring water for the drains of the capital, to improvement of inland navigation, to facilitating the construction of roads, and last but not least, to the possibility of extension of the area cultivated by the same population and the opening up of new land, the second question, set forth in the introduction of this Report, viz :—*Will irrigation and drainage be of utility for Lower Siam?* can certainly be considered as answered in the affirmative.

The produce of the soil would doubtless highly increase in quality, quantity and value and in consequence the value of landed property in the regions concerned will also increase very much, and therewith the wealth of the country.

The sanitary condition and domestic accomodation of the people also would be improved very much and so life would be made more comfortable.

III.

URGENCY OF IMPROVEMENTS.

The third question to be treated is: *Are improvements of the kind effected by irrigation and drainage required in respect to the present economical conditions of Siam?*

I will endeavour to answer this question from a practical point of view.

Lower Siam is not a famine stricken country. Up to the present the cultivators have always been able to stand even a couple of bad years, without being reduced to misery.

But certainly nobody will advocate a delay in bringing about economical improvements untill the country has become famine stricken.

What does however occur annually all over the lower provinces is a famine of drinking water. To provide for this most stringent want is certainly the first measure to be undertaken on behalf of the people.

This urgency however does not touch in the first place the economical side of the matter, which will be considered now.

Economical progress required.

Siam is a country in course of progress, in some respects of rapid progress.

Progress means, from a practical point of view, invariably increase of wants.

The wants of the Government are increasing, owing to reorganisation and extension of existing services, to establishment of new services, to extention of the efforts of the Government into matters already taken in hand and into new directions for the benefit of the people and the security of the State and so on.

The wants of the people are increasing, owing to more expensive habits and to the acquirement of new necessities and luxuries.

Closer contact with foreign trade has crushed out existing industries, which have disappeared before the competition of foreign manufactures, as for instance, Siamese sugar manufacture. Native cloth and metal manufactures will have had the same retrograde course as elsewhere in non-manufacturing countries.

The increase of imports in quantity, variety and value (from $ 10,872,016 in 1888 to $ 29,520,730 in 1901, (not taking into account the fall of silver currency), shows all this evidently enough.

Progress, increase of wants and of imports is not possible, in course of time, without increase of production and of export. The amount of export must always exceed the imports, at least in a country like Siam which cannot pay a part of her imports by rents due by foreign nations or money earned in foreign countries, but on the contrary has to meet liabilities abroad.

Now the Siamese have got on fairly well up to the present, the export having increased in a similar proportion to the imports and there is a proper balance (on an average $ $8^1/_5$ million in 1897/1901) in favour of Siam, more than sufficient to meet all kinds of financial liabilities abroad. Some increase of capital is apparent from the foreign trade returns.

The economical conditions, up to the present, are therefore from this point of view, certainly very satisfactory.

But Siam cannot remain stationary. It must go ahead under pain of decay, and it does so; no prejudices of religion or caste are paralyzing it.

Progress is going on rapidly and, in connection herewith, the wants of the Government and the people and the imports will continue to increase steadily; moreover in consequence of peace and enhanced security of person and property, the population will increase more rapidly also.

Rapid increase of production and of export, to meet the increase of wants, is therefore incontestably necessary for Siam.

For the present, there appear to be no possibilities other than agricultural, for the increase of production.

Jungle and forest produce is more on the way to become worked out than to increase.

The climatic and the present hydrographical conditions of the country prevent cultivation on large scale of other crops than rice.

Rice, however, is the most profitable cerial crop, which may be inferred from the fact that where in Italy, Egypt, the United States, etc. rice growing has become possible by artificial watersupply, the cultivators leave the cultivation of other cerials and take to rice growing.

To what extent the extension of arable lands will be able to provide for the increase of production, necessary for the progress and economical development of the country, it is difficult to ascertain.

The complaints with regard to the deterioration of Siamese rice, however, do not indicate that the extension of cultivated lands will provide a remedy in the future. The fact that the quality of rice grows worse, certainly indicates that the lands at present still available for extension, are in bad condition with regard to cultivation, so that it may be fairly considered that the time has now come to plan other means for the increase and improvement of the produce of the country.

From the experience in the klong Rangsit regions, the same conclusion must be inferred.

The rapidity with which the extensive regions, opened up by the Rangsit system have been populated and brought under cultivation shows most clearly that properly arable lands are wanted, and people prefer buying these better flooded and more accessable lands, to taking up waste Government land; though in the Rangsit province they have to pay for the land rather high to the first owners (20 to 50 ticals a rai, as I was informed) whilst they can take up the waste Government land quite cost free, and when brought under cultivation, can become owners of it by paying merely the fee for the title deed (1/4 tic. per rai).

This fact proves that the great abundance of waste land under present conditions is almost valueless for the people, so that extension of cultivated area, and increase of produce in that way,is limited not by lack of land, but by the unfavourable conditions of the land still available, which practically leads to the same conclusion.

If Siam does not, in due time, take precautions with regard to the development of its productive forces, the country may easily be soon placed in a difficult economical situation, similar to other countries which have neglected to take due measures in due time.

Should Siam on the contrary, take up the matter, it may by able to conduct the national productive forces to prosperity with results similar to those, which have been obtained in Germany and Japan.

Siam possesses resources of inestimable value in her incontestably very fertile soil, that will enable her to meet her future wants; but these resources must be developed.

The soil, though fertile, by its clayey character is very sensible to want of water, whilst the rainfall is scanty for rice growing, so that artificial supply of water is indispensable for good results.

As was explained, adequate irrigation and drainage will tend greatly to the increase of the production, but more than any explanation, a local example will convince and this example has been given by the klong Rangsit works.

The success, in many respects, of these works, which are a watersupply scheme of a very primitive character, namely inundation canals after the Siamese fashion, improved by a pair of locks to retain the water, has greatly contributed to the increase of the rice export of Siam in latter years.

By the effect of these works about $^3/_4$ of a million of rais of paddy land have come under cultivation and yield an average crop of about $3^1/_2$ millions of piculs of paddy a year.

The loss of land and produce by the continuous encroachment of the inundations by salt water is outweighed a great many times by these results, and the people driven from their lands by the salt water, among others, have found a prosperous livelihood in the Rangsit district.

The real importance of these results appears in due light, when compared for instance, with the probable economical results of such an important and succesfull enterprise as the Siamese Royal Railway.

The traffic of the railway amounted in the year 120 to 61.769 metr. tons or 1,018,000 piculs (of $133^1/_3$ lbs av.) of goods, among which 31.909 tons or 526,000 piculs of paddy and 122 tons or 2,000 piculs of rice.

The rice and paddy traffic of the railway represents the crop of about 100,000 rais of paddy-land, i e. about $^1/_7$ of the extent opened up by the klong Rangsit works. In this matter must be taken into consideration that transporting goods is not at all the same as producing goods, and that only a part, and most likely no more than a small part, of the goods transported have been produced in consequence of the railway having made the transport possible.

When a very primitive and incomplete scheme as the klong Rangsit works can show such results (the considerable loss of crop, suffered this year in the klong Rangsit territory by the water falling too soon, proves clearly the primitive character of the works as a means of watersupply) the success of a more adequate system can scarcely be liable to any doubt.

The consequences of an adequate irrigation and drainage system with regard to increase of quantity and improvement of quality of the principal crop, to fertilizing the fields by silt, to increase of garden cultivation and cultivation of dry season crops, to the possibility of extension of the cultivated area and opening up new land by the same population, to improvement of the sanitary canditions of men and live stock and to furthering of interior communication, undoubtedly will cause a great, and for many decades, a continually increasing augmentation of the national produce.

Revenue returns.

If the Government is to carry out irrigation and drainage schemes and assume the management and upkeep of them, next to the economical results, the question of revenue returns connected with the works, to counterbalance the expenses, is of great importance.

These returns consist of indirect and direct benefits.

The indirect returns come from the general increase of all kinds of Government revenue, in consequence of augmentation of produce and national wealth.

As the rice crop is the predominant resource of the national wealth of Siam, it can be considered as a matter of course that the Government revenue in general is most nearly connected with the results of the rice crop, so that no elaborate explanation will be needed on this point.

In Siam the increase of export duty and fees on rice (about tic. 3 per ton) and paddy would be rather a direct, than an indirect return and moreover an important one, as the bulk of the the increase of crop in all probability would be exported.

For the import duties and most other headings of revenue the connection with the result of the rice crop is also most obvious. *

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* *See next page.*

The direct revenue from irrigation and drainage works would consist of water-taxes, water-rates, tolls and lock fees and sale or rent of land.

A water tax could be levied, in a manner similar to the paddy land tax, over the whole area at present cultivated and the future extension of this area, as far as the fields are benefited by the system. This seems to be the most suitable way of raising revenue from the paddy cultivation.

In a rice growing country, like the plains of Lower Siam, where rainfall is insufficient for the crop and of short duration, whilst the farmers want a long period for their agricultural operations in connection with the extensive lots of land they generally work, the question whether the cultivators will make use of the irrigation water, if supplied, apparently without any reserve may be answered in the affirmative. One must have seen the cultivators toiling for water by pumping and scooping, all over the country, to know how badly a regular supply is wanted.

Water rates could in general be assessed in some proportion to the quantity of water utilized, and would most probably be a suitable taxation for dry season crops and garden cultivation.

Tolls and lock fees will make a fair return for the improvements in behalf of the inland navigation on the canals to be constructed and to be improved and are likely to procure a very important amount of revenue, considering the figures about boat traffic in the klongs, mentioned, on p. 58 which show how extremely ferquented the existing klongs are.

Obviating loss of revenue in consequence of failure of crop will also represent a financial result, as may easily be concluded from the fact that the paddy landtax is assessed on the area producing crop, except in the circle of Krung Kao where the assessment is based on the area under cultivation.

Another financial result will be, that the cost of the future town water works for Bangkok will be reduced at least with half the amount, and also the

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* The relations between the imports and the value of the export of rice appears most clearly from the following abstract of the Bangkok trade returns.

	Export. $	Import. $	Balance Export. $	Rice Export in English tons.	Value Rice Export. $	Remarks.
1897	30·585·982	24·584·042	6·001·940	(1) 557·700	23·426·193	(1) According to the returns of the Custom-house the average price of rice in 1887 was about $ 2.50 per picul only, against about $ 3.20 on an average in the 4 following years.
1898	34·613·875	27·090·162	7·523·713	519·200	27·581·544	
1899	32·072·988	25·998·409	6·074·579	445·300	22·834·160	
1900	31·203·228	26·036·615	5·166·613	414·400	22.481·658	
1901	45··322·036	29·115·358	16·206·678	682·300	36·160·995	

working expenses will be reduced very considerably, as the pipe conduit and the pumping station to convey the water to the capital can be omitted. (see p. 51).

Sale or rent of land at present waste, which all is property of the State and to a great extent will be rendered more accessable and cultivable in consequence of the canals to be dug, will also make an important heading of revenue.

Waste land is abundant in the area concerned, about 40% of the extent only being cultivated, and a considerable extension of cultivated land may undoubtedly be expected in consequence of the possibity of extension of the area that can be cultivated by one person.

The Rangsit canal Company's financial success shows the possibilities in this direction.

That irrigation works can give a fair return, may for instance be inferred from the last Report of the British Indian Public works Department, where it is stated that the average direct net return of all the Government irrigation works (all expenses for management and upkeep deducted), have been:

in the season 1897-98 7·50 % of the outlay
" " 1898-99 6·80 % " "
" " 1899-1900 6·92 % " "
" " 1900-1901 7·33 % " "

Irrigation works in Lower Siam would be in more favourable conditions than the average works in India and may be ranged rather on the same line as the works for the ricegrowing deltas of the Godavery and Kistna rivers in Madras which pay a net revenue of 12 to 14% on account of watertaxes and rates only.

(In Java the Government returns of irrigation works are included in the landtax and separate accounts are not kept.)

Considering these results, irrigation works appear not only necessary from an economical point of view to further the produce of the country, but may become at the same time also a very profitable Government investment.

To what proportion the latter will actually be the case, principally depends of course upon the regulations concerning the returns to be paid, and is therefore controlled by the Government itself.

As a conclusion, from what is explained above, to the question: *Is bringing about an irrigation scheme required for Siam?* in my opinion, only an affirmative answer appears to be possible.

IV.

OUTLINES OF THE PRINCIPAL SCHEME.

The possibilty, the utility and the urgency of irrigation and drainage schemes in general having been discussed, the outlines of the principal scheme for Lower Siam will now be traced in a more definite manner

The principal scheme relates of course to the great Menam, the most powerful source of supply, and the Menam plain, the most extensive region to be supplied.

Moreover, it is only concerning the Menam and the Menam plain that sufficient facts and figures are available to trace the outlines of a scheme with any exactness, and besides there are a great many canals and channels in the Menam plain that can be used for the purpose, which will reduce the expenditure on the works and the time of construction very considerably.

Water supply most required in the Lower Menam Valley.

The rainfall statistics indicate that in the lower plain of the great Menam and in the adjacent flat regions the rainfall is much less than in the Northern, South-Western and South-Eastern provinces of the Kingdom. (see p. 20).

This fact is in accordance with the general opinion in the country, founded on the unrecorded experience of centuries, as was told me in several localities, and can be virtually explained by the natural situation of the plains concerned, quite near to the east side of the high hill ranges, between Siam and Lower Burma, that retain the south west monsoon rains. In consequence thereof in Pegu and Tenasserim the average rainfall is twice as great as in the lower Menam plain.

This influence of the hill ranges of course, decreases with the distance and seems already to be of much less effect in the Prachim regions.

The parts of the country that are most in need of water supply are therefore the Lower Menam Valley and the adjacent plains of the Meklong and Bangpakong rivers.

Amelioration in these parts would besides be of more direct utility than anywhere else in the country, because these plains (as is the case everywhere with the low plains) are the most densely populated and most cultivated regions of the country, a circumstance which is due to the vicinity of the sea and to the facilities of communication and cultivation, produced by the big rivers and the flatness of the soil.

The rivers available for taking off irrigation water are, as already stated, the great Menam and its tributary, the Pasak river, and further the Meklong river and the Bangpakong river, with its tributary, the Nakon Nayok river.

It is fortunate that the most important rivers run just through the parts of the country that are most in need of water supply; in consequence thereof irrigation works will become considerably less expensive than if the water had to be obtained from distant sources.

Supply Lower Menam Valley to be taken off the great Menam.

The natural situation of the regions concerned points, as a matter of course. to the use of the water of the powerful Menam to irrigate the whole Lower Menam Valley on both sides of that river, reaching to the Bangpakong river at the east side and to the lower part of the Meklong river to the west side.

To deal with of the great Menam for the offtake of irrigation water requires of course great and expensive works, and if the water could be obtained from several smaller rivers, spread over the country, this would facilitate and cheapen the execution of the scheme considerably, as small rivers in general are easier to be dealt with than big ones, and numerous offtakes at several places would only require small canals.

In the lower Menam plain however, no other river, reliable for irrigation purposes exists, so that there is no choice where to take the water from and the matter has to be faced as it is.

Although it may be of no advantage, from the point of view of expenditure, that only one big river is available, from a point of view of watersupply a big river, like the great Menam, is preferable, as being much more reliable for a regular offtake than smaller rivers would be.

Small rivers firstly have the disadvantage that their catchment areas are of little extent so that there is little chance that the freshes from the drainage areas of the different tributaries will compensate each other so as to make the discharge of the main river fairly regular; and secondly that generally the catchment area is too much in the vicinity of the area to be irrigated, so that drought and great want of water in the last, as a rule will correspond with a small discharge of the river.

It would be possible to utilise the water of both neighbouring rivers, the Meklong and the Bangpakong, and also of the Pasak river on behalf of some parts of the lower Menam plain, but both because of the discharge of these rivers, specially in the dry season, being too small and because of their situation and elevation in relation to the Menam plain, only a small, most likely not even a fourth part of the lower Menam plain could be served by these rivers.

Therefore to use these rivers for some parts of the lower Menam plain would not dispense from dealing with the great Menam after all.

Moreover these rivers all are rather powerful and not so close at hand, that to utilise them would tend to safe expenditure; most likely the contrary would be the case.

Besides, these rivers all have extensive plains along their own course, which for an artificial water supply exclusively depend upon them.

The only way to water the lower Menam plain so proves to be to take the water off the great Menam.

The water of the Pasak, Meklong, Bangpakong and Nakon Nayok rivers then can all be employed for the extensive plains crossed by the higher reaches of each of these rivers themselves.

Weir necessary across the great Menam; inundation canals undesirable.

It being thus ascertained that the supply for the Lower Menam Valley has to be taken off the great Menam, further the question arises how to get command over the water, so as to have it conducted into the canals for distribution over the fields, instead of flowing away to the sea.

Pumping the water is of course excluded before hand as being too expensive for the great quantities required.

As an answer to this question it is determined beforehand by the natural situation of the country that the least expensive way to get command at all levels over the water of the great Menam on behalf of the Lower Menam Valley, is to construct a weir across the river with movable dam.

This matter will be explained further in detail, because it is connected very closely with the whole scheme.

Practically there are two ways to get the water of the rivers throughout the whole year permanently on the level, required for irrigation in the area under command, namely constructing weirs across the rivers, and constructing canals which run more or less parallel to the main direction of the rivers and have a less rapid slope than the river, so that as their course proceeds, the waterlevel of the canals will grow continually higher above the waterlevel of the rivers in the same tract, and finally will reach above the level of the fields.

If now, as is the case in Lower Siam, as a rule the fall of the winding rivers is about the same as the fall of the ground, then of course it will always be possible to construct straight supply canals, which have a less rapid slope than the rivers, in such a way that at the end the water surface of the canal will reach the level of the fields, even when the water in the river is lowest.

Before it reaches this point, the water of the canal does not become available for the purpose.

From the place it is taken off from the river to the place where it becomes available, the canal has the same effect as a weir across the river would have, by the aid of which the water could be dammed up so as to be available in the same locality in which the weir is situated.

Such a canal, in Lower Siam, to get the water at the level required for irrigation would be very long and expensive.

The height of level to be gained on the ground-level by the level of such canals is the difference in height between the surface of the fields and the lowest level of the river in the reach, that crosses the locality where the water must be available.

This is about 7 M. in the case of the great Menam.

The average slope of the soil in the upper parts of the Lower Menam Valley can be taken as about 1/8000 [0.125 M. in a K. M.] and it would not be advisable to give the canals a much less rapid slope than 1/20,000, [0.05 M. in a K. M.] as this most probably would cause trouble by the deposit of silt in the canal. In these circumstances a gain of level of 0.075 M. in every K. M. would be obtained, so that to gain the total height of 7 M., necessary for perennial supply, would require a canal of a length of more than 90 K. M.

These canals (one on each bank of the river) which would require a capacity of discharge of at least 200 $M.^3$ per sec. would of course have to be dug very deep (about 10 M. at the head).

If the depth of water at full discharge in such a canal is 6 M., then a surface slope of 1/20.000 will produce a current of about 0.80 M. per sec and in that case the canal on an average would require an excavation of about 300 $M.^3$ earth per M. length, which would be, for two canals of 90 K. M. length each, about 54 million $M.^3$ of earth-work.

Even at the moderately estimated cost for such deep and wide canals of ½ ticals per $M.^3$ and without accounting sundry expenses, the amount of money (27 million ticals) required to dig two canals in order to get the water on a proper level, would be many times greater than would be the costs of a weir with movable dam across the Menam, which may be estimated at about 6 million ticals.

Moreover the area commanded by the supply works would become considerably reduced, in the case such canals were constructed, as may be concluded at cone from the natural features of the Lower Menam Valley.

Not only perennial canals, to get the water on the level of the fields, would be much more expensive than a weir, but even inundation canals, answering to very modest requirements would cost more.

If for instance inundation canals were constructed, that could not draw off sufficient water before the river had risen 3 M. above its low level, the height of level to be gained would still be 4 M. and the length of the canals about 55 K. M., whilst the quantity of earth to be excavated on an average can be estimated at more than 200 $M.^3$ per M. length of canal. Thus in this case the costs of the earth-work alone for the two canals still would be, at the rate of $^1/_2$ tical per $M.^3$, about 11 million ticals, that is to say about twice as much as the probable outlay for a weir, which would secure perennial supply.

Inundation canals of the latter kind would of course be very much better than no supply at all, and also much better than the present Siamese inundation klongs, because the available quantity of water would be much greater and the period of supply much longer; but nevertheless they would only provide water during the season of heavy rains and a short period after and so a great part of the advantages connected with perennial irrigation, as for instance the supply of drinkingwater in the dry season, would be missed, whilst a weir of course always provides for a perennial supply.

At the international congress of Civil Engineers at Glasgow in 1901 the Director General of Irrigation reservoirs in Egypt, Mr. W. Willcocks, reported the average value of crop of the fields that get water supply by the Egyptian inundation canals to be £ 7$^1/_2$ and of the fields that have perennial irrigation £ 12$^1/_2$ per H. A., whilst the value of crop of the field without any artificial supply was estimated at £ 2$^1/_2$ per H. A.

In all probability the differences will have a similar proportion in Siam and will be enhanced by the fact that the great prolongation of the time available for cultivation, caused by perennial canals, is particularly of high value for Siam, in connection with the possibility of extension of the area under cultivation.

In Siam the construction of inundation canals would not therefore be advisable (even if they were less expensive than perennial irrigation, as evidently is not the case); even less so in Siam than in Egypt, where millions of pounds have been spent to convert inundation canals into perennial irrigation canals.

From the considerations above mentioned, even non-experts will infer that canals parallel to the rivers to get the water at the required level, as well as inundation canals, are quite unfit for Lower Siam, if only with regard to the expenditure on construction.

Besides the financial, there are also technical disadvantages, connected with the said system of canals, since they are liable to silt up in consequence of slowness of the current, and so for that reason too this system is little desirable.

It is therefore clear, that the construction of a weir would be the most advantageous and least expensive way to get command over the water of the great Menam.

A weir across the great Menam would necessarily be constructed with a movable dam, for if the power to dam cannot be diminished and removed at the time of high water, the river would have to be heavily embanked for an enormous distance above the weir, in order to prevent overflowing of the banks to such a depth as to spoil greatly the works to be constructed and to cause the greatest damage by making extensive regions quite uninhabitable and uncultivable for many decates (until the banks have been raised sufficiently, in consequence of the overflowing) even for the people and paddy of Siam, so well accustomed to floods.

The construction of high embankments of the kind required would be very expensive, amounting probably to about 3 millions ticals, whilst it will make no great difference in the cost whether the future weir is constructed as a movable dam or not.

What has been explained above with respect to the great Menam, is in principle also the case with the other available rivers mentioned, which, as already stated, have a similar régime and are proportionally in similar conditions with regard to elevation and slope of the soil.

Site of the weir and headworks.

The site of the offtake and headsluices is a question of predominant influence on the whole system, so that this question has to be examined before the scheme can obtain any definite shape.

In the case of the great Menam the place where the required offtake should be situated is easily decided by the consideration that a weir is necessary and by the natural features of the country.

The lower Menam plain is divided by the great river into two not very unequal parts, which are each of them to be irrigated by a separate canal system. It would of course be possible to combine both principal canals into a single one; this however would not decrease the total of the excavation, and the expenditure on that account, and it would, on the contrary, increase the costs of the works very much by requiring aqueducts across the river, very expensive and moreover to some extent obstructive to river navagation.

Again the two canals thus required for the Lower Menam Valley could be derived each from one of the two principal branches of the Menam, the Nam Ping and the Nam Po, which flow together at Paknampo; but against a scheme of this kind, there are most serious objections.

The proportion in which each of the two branches contributes to the discharge of the main river is not sufficiently known, to be sufficiently certain about the regularity of the supply for each of the canals. Especially the Nan Ping, which has somewhat the character of a torrent and shows sudden rises and falls of some feet in a few hours, seems less reliable, the more as the right bank part of the Lower Menam Valley is more extensive than the left bank part.

The regularity of the main river, however, can tolerably well be relied upon; but if this equally was the case with both tributaries and their discharges were in the proportion, required for the respective extent of the areas on each bank of the main river, then it would not yet be advisable to separate the supply, even if it would tend to save expenditure, because the chance of irregularity of supply would be enhanced, as in case of separate supply each system is liable to the full alternation of discharge of each tributary, whilst the alternation of both branches are likely to largely compensate each other with regard to the discharge of the main river, so that the combined supply will secure considerably more regularity of supply in both canals.

Apart from this, moreover the construction of two weirs, one for each powerful tributary, would in the present case in all probability be considerably more expensive than to make only one weir in the main river, construction of weirs being the most advisable way to get command over the water, as well for both tributaries as for the main river.

In the case of the Nam Ping the slope of the soil is certainly considerably more rapid than in the case of the main river and the eastern branches, and in that case comparatively it would not be so difficult and expensive to make a canal to get the water at the required level as in other cases; but notwithstanding that, there is no doubt that even in that favourable case, such a canal would cost much more than a weir, the more as the canal would run across the drainage line of the valley of the Nam Ping.

From what is explained with regard to the matter, it is to be inferred that an adequate irrigation system of the lower Menam plain will require the construction of a weir with movable dam in the *main river*, below the confluence of the principal tributaries at Paknampo.

The further upstream a future offtake and weir for irrigation purposes is situated, the greater in general will be the extent of the irrigable area under command, but also the longer will be the principal canals; and one of the first points, when fixing the place where an offtake is to be made, is therefore to consider in how far the increase of expenditure caused by the increase of length of the main canals, is counter-balanced be a sufficient increase of area under command.

Thus taking into consideration the relation between the lengthening of the main canal and the increase of area under command, Chainat is assigned as the place, in the vicinity whereof the weir should be constructed.

From Paknampo down to Chainat the left bank of the great Menam is flanked by ranges of low hills and high ground; and on the right bank also, though at a greater distance, there are several hills, partly dispersed, partly in ranges, whilst moreover on the right bank the soil has a rather rapid slope to the river. This must be inferred from the main direction of the right bank tributaries of that reach of the great Menam, which at some distance from the river becomes nearly quite west-east, a circumstance which indicates that the west-east slope of the ground in these parts is so considerable, in comparison with the general north-south slope, that the main direction of the drainage is not virtually affected by the latter.

The additional strips of land which would be brought under command if the weir were constructed at a place further upstream than at Chainat, would be narrow on both banks in consequence of the hills mentioned and the more rapid slope of the soil in west-east direction. Both strips together would at best have a breadth of about 10 K. M., so that it is most certain that this increase would not compensate for the expenditure on lengthening the big main canals. To compensate for this expenditure a breadth of 30 K. M. of land is at least required.

On the other hand it will be possible to combine irrigation of these narrow strips of land along the main river with future, less extensive schemes of providing the plain above Paknampo with water supply from the two principal tributaries.

In this manner the supply for these strips of land can be acquired at much smaller cost, because then the canals to be lengthened will not be the big canals for the whole Lower Menam Valley, but serve only for the narrow tracts concerned, for which purpose small dimensions will be sufficient.

As the population of these regions is thin and people are all living near the river, there is no special or immediate urgency for watersupply in these parts.

For a relatively small offtake in behalf of the plain above Paknampo, the regularity of the discharge of the tributaries certainly will prove to be sufficient; but to what extent water will be available for that purpose, of course, must be investigated and determined by regular observation about the discharge.

Below Chainat the hills cease and the broad flat plain stretches far out on both sides of the river, so that the area under command of irrigation canals here at once becomes very extensive.

To continue the outlines of the scheme for the Lower Menam Valley, it must firstly be observed that the vicinity of Chainat as a site to construct the weir. has still some other advantages, besides its situation at the place where the hills cease, and the flat plain begins to be very extensive on both sides of the river.

Just below Chainat is the mouth of the Menam Nawi (or Menam Noi) probably an old local natural drainage channel, that has been connected by an inundation canal with the great Menam and is thus grown into a river arm, running on a ridge.

This Menam Nawi runs down to Angtong, and by the intermediary of the klong Poh Tjam Sui, provides the region of the klong Pekaitalan with water during flood time; which can however be done with nearly the same effect by another river arm, that branches off the great Menam below Angtong.

Besides, at the time of the very highest flood, a consideradle tract of land along its course is inundated during some days by the Menam Nawi. At its mouth however the bottom of the Menam Nawi is about 3 M. higher than the lowest level of the great Menam, and consequently as soon as the great Menam subsides the discharge of the Menam Nawi decreases very rapidly and the flooding ceases. Moreover the offtake of the Menam Nawi is obstructed considerably by a sandbank, its mouth being very unsuitably located on the convex bank of a winding of the great Menam. According to local information, the Menam Nawi must have been somewhat decreasing in depth and width during latter years.

Under present condition, therefore the Menam Nawi is of little and decreasing value.

Nevertheless the channel of the Menam Nawi, with some not very expensive improvements, will provide a very adequate main canal for a perennial irrigation system, with a capacity of discharge of about 250 $M.^3$ per second and situated on a ridge of about the same height as the banks of the great Menam.

The downstream end of the Menam Nawi is connected, by the klong Poh Tjam Sui, with the comparatively small right bank Menam branch, named the Menam Seekook. This river branch, which for the greatest part appears to be an artificial one, with some improvements, over a distance of about 30 K. M., also will be usable as a main canal in a perennial irrigation scheme.

The Menam Nawi, combined with the klong Poh Tjam Sui and Menam Seekook, in connection with a perennial irrigation system, represents a value of at east about 10 million ticals.

To make use for irrigation of the Menam Nawi and other arms of the great Menam, it must be observed, will not tend to diminish the maximum discharge capacity of the river and to overcharge the main channel, because the regular offtake for irrigation purposes will be about equal to or greater than the maximum discharge of the branch channels under present conditions.

Besides overcharging of the main channel to some extent in the present conditions of drainage and supply, would cause little anxiety. Most likely people would even face the fact with satisfaction.

To prevent undesired overflow of the rivers is further a matter connected with drainage, and will be considered together therewith.

As the mouth of the Menam Nawi is near Chainat, in this respect, this place is very favourable as the situation of a weir and offtake, because here it would be very easy to connect the head-works with the Menam Nawi channel by a short cut.

A situation further downstream would entail the excavation of a canal of considerable length from the great Menam to the Menam Nawi and would thus be more expensive with regard to the right bank works.

On the left bank there are no suitable existing channels, that can be of influence with regard to the place of the weir; but the flat plain at the left bank is rather broad and sloping eastward, and so it seems that, even without regard to the advantages connected with Chainat as site of the head-works in respect to the right bank, on the left bank the increase of area will be sufficient to counterbalance by itself the lengthening of the future left bank main canal.

The situation at Chainat would further procure the advantage that the neighbouring quartzite hills could be used as quarries to provide stone for the weir. The river itself carries good quartz sand and small gravel.

From the vicinity of considerable hills, moreover, it may in all probability be concluded that a solid foundation ground will be obtainable, the more as at some places in the vicinity solid rock crops out at the bottom of the river.

A weir in the vicinity of Chainat would at the same time, and better than one at a place lower downstream, secure the perennial supply of the klong Makamtau by which the Supan river takes off water from the great Menam.

The Supan river is either a decayed natural discharge branch of the great Menam or a local drainage channel of small importance, that in an accidental or artificial way has been connected with the main channel and so has grown into a big watercourse, a present however with very little water, as the drainage area is small and the connection with the Menam is in decay.

Under present conditions the Supan offtake is working only during the time of very high level; but the channel has a capacity of about 200 M.^{3} per sec and is large enough to be suitable as a main canal for irrigation purposes, at least over the first 100 K. M. of its course, where it runs on a considerable ridge. The lower parts of the Supan river are less suitable for irrigation purposes, and also not available, as they are required for drainage purposes.

The highest part of the klong Makamtau is rather small and has an unsuitable direction. However, by making a cut of about 1 K. M. length from the great Menam to the klong Makamtau in the vicinity of the village Bang Hata Sao, the offtake will be brought about 5 K. M. nearer to Chainat and at a most suitable place on the concave bank of a winding of the main river, where the danger of a sand bank rising in front of the headsluice is not at all to be feared.

The channel of the klong will, by this cut, be shortened by about 10 K. M.

According to what has been explained with regard to the matter, it will be obvious that a weir, to be constructed across the great Menam in the vicinity of Chainat, must be considered as the base of the whole irrigation scheme for the Lower Menam Valley.

Headworks.

The weir itself must be provided with a movable dam to prevent the necessity of making high embankments of an enormous length along the river.

The dam will consist of numerous piers and openings, the total length of the weir being about 200 M. The openings have to be opened or shut according to the rise and fall of the level of the river above the dam. Further details will be omitted here; it need only be mentioned that numerous constructions of that kind exist and operate successfully.

The ordinary waterlevel above the weir will be about equal to the height of the banks (i e. about 24 M. above the ebblevel of the sea) in order to be able to irrigate not only all the fields in the immediate vicinity of the dam, but to benefit also a considerable extent of land along the river-reach above the weir, lying a little behind and lower than the highest part of the banks.

During the greatest part of the year the weir will have a considerable head (difference between the level above and below the dam) with a maximum of about 7 M. In porportion to the head at the dam growing higher the current in the river-reach above the weir will be slower and in consequence thereof, a great part of the sand and coarse silt will be deposited above the dam, and so prevented from entering and obstructing the canals, whilst principally only the fine, light and most fertilizing part of the silt will come into the the canals.

At the time of high flood however, the head at the weir will become very insignificant and rafts and even boats with some precautions will be able to pass the dam. During this time the current upstream grows strong enough, as experience with similar constructions has proved, to scour away and carry down the river all the sand and coarse silt deposited above the dam during the rest of the year.

The main canals, as well as the offtake for the klong Makamtau, must of course be provided with headsluices to regulate the inlet of the water, while to keep navigation and rafting open, locks will have to be made, connecting the up and down-stream reaches of the river with the canals and with each other.

The headsluices will be constructed as simple regulating bridges with wide openings, situated as near as possible to the dam, and arranged in such a way that at high flood time the water is taken off as near to the surface of the river as possible, so as to prevent useless and obstructing sand and coarse silt from entering into the canals.

Wide scouring vents, to prevent depositing of sand immediately before the headsluices of the canals and the navigation locks, of course are required.

Fish paths may be taken into consideration, to enable communication for fish, travelling for spawning, and also a slide for rafts.

The reservoir-like part of the river above the weir will make a magnificent fish basin and storing place for timber.

The weir across the great Menam will become a work of great interest from a technical point of view and a monument to the efficacy of Siam's Government.

Capacity of the headworks; extent of the area.

The capacity of discharge of the headsluices by which the water is to be drawn from the great Menam and of the highest parts of the main canals is now to be examined.

The capacity of the headworks depends, of course, on the extent of the area under paddy cultivation, influenced by the system.

The limits of the area under command of a weir and offtakes as proposed have been determined as precisely as possible by the available elevation-figures, by the direction of the river branches, and by local inspection; the results of this investigation may be admitted as a fair approximation, and are indicated on the annexed map.

The area at present under cultivation, which will be influenced by the main canals and Supan river works referred to, is about the whole extent of the cultivated lands of the *circles* * of Krung Tep, Krung Kao, and Nakon Chaisi, and further of the *provinces* Chainat, Petrew and Meklong (Samut Sang Kram).

According to the assessment of the paddy landtax for the year 120 (1901-1902) the extent of the paddy fields under cultivation is in:

the *circle*	Krung Tep	983,240	rais. **
„ „	Krung Kao	2,360,000	„
„ „	Nakon Chaisi	557,323	„
„ *province*	Chainat	107,2~~2~~55	„
„ „	Petrew	415,180	„
„ „	Meklong	14,458	„
	Total	4,437,456	rais.

These figures may be considered as tolerably exact, 3.380.450 rais of the extent being already cadastrally surveyed previons to the year 120, as is stated in the annual Report of the Royal Survey Department for the year 119.

As a total of the area under paddy cultivation in the region under command of the future works, 4.437.456 rais however will be far from being quite exact.

In the first place it must be observed that some parts of the *circle* of Krung Kao and of the *province* of Chainat lie outside of the area under command; of these regions however only a very small part is under cultivation. On the contrary some parts, other than the Meklong and Petrew *provinces*, of the *circles* Ratburi and Prachim are lying within the area under command; these part are not taken into account, as a compensation for the regions referred to outside of the area.

I was not in the position to examine in how far these circumstances counterbalance each other with any exactness, as the limits of the area under command could but very roughly be determined, and moreover these parts lie outside of the sphere where the cadastral survey has worked, up to the present. In all probability however the total extent of the cultivated area under command will be somewhat greater that the stated figures, but not so much as to be of considerable influence on the general calculations founded on the figures as they are.

The total surface of the area concerned is about 1,870,000 H. A. or 11 million rais, so that about 40% of the total surface appears to be under rice cultivation.

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* A *circle* (monthon) is under a High Commissioner and contains several *provinces* (muang), under Governors.

** A Siamese rai = a square sen = 1,600 M.^{2}.

The total of the cultivated area of paddy fields for the whole of Siam, according to the figures of the estimate of the paddy landtax for the whole Kingdom in the year 120 (tics. 2,914,389, including tics 590,000 for the *circle* Krung Kao), is 8,558,371 rais. *

From these last figures it follows that considerably more than half the cultivated area of Siam is situated within the area under command of the proposed irrigation system.

With regard to the total produce the area under command of the canals will represent no smaller percentage of the whole of Siam, and with regard to export of rice it will represent most likely much more than $^{3}/_{4}$ of the whole of Siam, because the extent of land worked by one person is greatest in these regions, as was explained, so that here a greater percentage of the crop is not required for local use and can be exported. **

The quantity of water to be supplied by irrigation is the quantity necessary for the rice crop, diminished by the available rainfall. The quantity of water required for the crop during the time of vigorous growth, may be estimated at 1.55 L. per sec. and per H. A., (equal to 40 c. m. rainfall per month), as was explained on p. 16.

From the rainfall statistics it must be inferred that the ordinary rainfall during the months of August, September and October, when nearly the whole rice crop is still on the fields and the greatest part is about to require full watersupply, may be reckoned at about 8 inches (equal to 20 c. m.) a month. (Average over 1882/'91 in August 7.06, September 11.38 and October 8.20 inches.)

Considering $^{4}/_{5}$ of this quantity or 16 c. m. as really available for the crop, (in times of scanty rainfall the losses by flow-off will likely be less), the quantity of water to be supplied by irrigation would be equivalent to 40 minus 16 or 24 c m. of rainfall per month.

A monthly rainfall of 24 c. m is equivalent to a watersupply of about 0.9 L. per sec. and per H. A.

This supply requires for the area of about $4^{1}/_{2}$ million rais or 700,000 H. A. at present under cultivation and to be commanded by the system proposed, a quantity of water of about 630 $M.^3$ per sec.

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* The paddy landtax is $\frac{3}{8}$ tic. per rai *actually producing crop*, except in the *circle* of Krung Kao, where the tax is $\frac{1}{4}$ tic. per rai *under cultivation.*

** According to the investigations of the Royal Railway Department, in ordinary years no more than about 11.400 $M.^3$, equal to about 120,000 picul, paddy comes from the regions above Paknampo. This represents about 1% of the average rice export of Bangkok in ordinary years (about 8 million picul rice, equal to about 12 million picul paddy).

During the months of the season of the paddy cultivation before August, it can be reckoned that a great part of the crop is still very young and does not yet require a full supply. *

This will necessarily always be the case, because labouring, sowing and planting of the fields must go on successively, and will take most cultivators at least two to three months, in view of the extent of land they generally work.

Soaking of the fields by artificial supply will for this reason also only be required successively, during the period the requirements of the crop are still non-existent or small. But soaking of the fields will take large quantities of water. For instance, from experiments in the plain of Demak (Java) results that 2.51 L. per sec and per H. A. during a fortnight is required for that purpose, against 1.55 L. at the time the paddy is in full course of growth. The space of time however over which the function is devided is so long in Lower Siam, in connection with the time people generally need for labouring the whole of their fields, that certainly the ordinary supply will meet the requirements on behalf of soaking without difficulty.

After October a great part of the early ripening paddy is already reaped or is in such a stage of maturing that it requires little or no water.

As the supply will be about the same during the whole season of paddy cultivation, the lesser rainfall in the months after October therefore will be compensated sufficiently by the lesser wants of the crop.

In years of very scanty rainfall it would certainly be desirable that the supply should be somewhat larger than 24 c. m. per month ; but still in the driest year recorded (1884), the rainfall and this artificial supply together in August (rainfall 3.57 inches =9 c. m.), the driest month of the period of highest requirements (August, September and October) would have been equivalent to 9+24=33 c. m. of rainfall, i. e. about 65% more than the present ordinary rainfall in these 3 months (about 20 c. m.) and still 7% more than the maximum rainfall, recorded in August in the period

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* The supply of irrigation water in the area of the Demak system (Java) is based on the following scheme of agricultural requirements.

Water required for	Soaking	Labouring	Course of growth						Ripening.
Period in weeks	2	5	1	4	2	2	2	2	2
L. per H. A. and per sec. supplied.	2.51	0.31	1.03	1.55	1.24	0.93	0.62	0.31	0.00

The duration of the period of full supply is here chiefly determined by the quantity of water available, and not by the quantity desirable.

1882-91 [12.14 inches=31 c. m. in August 1890]. In the months before August and after October the mentioned artificial supply alone will always be at least more than 50% greater than the average rainfall.

To arrange the whole system according to the full requirements of the most scanty rainfall would lead to considerable extra expenses on enlargements, that only in these years of most scanty rainfall would procure their full economical effect; but in ordinary years the utility of the extra expenditure would not be fully proportional to the utility of the expenditure based on the ordinary requirements.

It appears therefore most advisable to arrange the scheme according to the requirements of ordinary years, in order to have proportionally the greatest results of the outlay on the works.

Extension of the area under cultivation.

To anticipate the future increase of the cultivated area, however, it will be advisable to construct the works with regard to a larger capacity of discharge than strictly would be required for the present area under cultivation, and to keep in view the probability of further increase of capacity.

The rapidity with which the extensive regions opened up by the klong Rangsit system have been populated and brought under cultivation shows clearly that suitable land is wanted in Lower Siam, so that a considerable extension of cultivated area may be expected in a rather short period.

A great extension even will already have been realized before the future irrigation system can come into operation, in consequence of the completion of the klong Rangsit system, which will take a few years only.

This extension will be about 400,000 rais, as the total area embraced by the Rangsit system is 1,500,000 rais, of which about 20% is to be deducted for villages, gardens, canals, roads, uncultivable high localities, swamps etc. and more than $^3/_4$ million rais has already been cultivated.

When a few years after the completion of the Rangsit system the whole area, as far as cultivable, will be brought into cultivation and no other suitable land will be available at the time being, the extension, to be rendered possible by the irrigation works, might even be seriously required.

A part of the population of the klong Rangsit regions has come from those tracts, where people have been obliged to abandon their lands in consequence of inundation by salt water, encroachment of bad weeds etc. In the future further spoiling of land will of course be prevented as much as possible, but migration from spoiled tracts has furnished only a small part of the Rangsit population, as the whole area spoiled during the last decade certainly does not exceed 50,000 rais, whilst in the Rangsit province about $^3/_4$ million rais have been brought under cultivation in the last 6 or 7 years.

The whole area of spoiled land, it may be observed by the way, will be about 300,000 rais, but the process is going on during many decades already.

The bulk of the Rangsit population comes from most various regions of Lower Siam and adjacent provinces and represents an increase of population, not required for the tillage in their native localities. The last may certainly be inferred from the fact that the paddy landtax as well as the rice export generally are increasing.

In connection with the above considerations, an extension of 20% of the area at present under cultivation may certainly be expected within a short period after the future irrigation works can come into operation. This would make not much less than 1 million rais, of which about 400,000 for the Rangsit district.

As long as the extension of cultivated area anticipated is not entirely arrived at, the supply for the area under cultivation will be somewhat on the right side and occasions of very scanty rainfall will more largely be provided for.

Capacity of the headworks (continued).

Besides the probable extension, also the loss of water in the canals by evaporation and percolation must be taken into consideration; but on the other hand the canals will have a gain by receiving a considerable quantity of drainage water from the catchment areas of the existing channels to be utilized. The loss by percolation sometimes, in sandy and hilly regions, can be a weighty factor, but will not be very great in the flat and clayey soil of Lower Siam. For the same reason, on the contrary, the gain on account of drainage however may be more important.

Moreover, as mentioned, it will scarcely ever occur, even in the three months period of greatest want, that the whole area under command requires full watersupply at the same moment, because in general one part of the crop will still be too young or another part already too far matured to need full supply.

As neither the losses in the canals by evaporation and percolation can actually be ascertained, nor the gain of water from drainage and the lesser want in consequence of the entire crop never being at the same time at the same stage of full requirements, I venture to consider that they will outweigh each other for the greatest part, and therefore provisionally may be neglected.

Moreover the greatest part of the water supplied artificially will be evaporated by the plants and from the surface of the fields. This part will exceed the local rainfall almost in every month; in consequence the humidity of the air will be greatly enhanced and the temperature will be lowered. Consequently the local rainfall must increase and grow more regular.

Under these circumstances, any discharge capacity of the works greater than strictly required for the present area under cultivation, may be considered as entirely available on behalf of extension of the cultivated area.

In connection with the above considerations it seems desirable to take the discharge capacity of the main canals at about 20% greater than the quantity of 630 $M.^3$, above mentioned, and fix it at 750 $M.^3$, in order to render possible the extension of the area at present under cultivation of about 20%, or nearly 1 million rais, which was referred to.

From provisional investigations it must be inferred that about 5/12 part of the cultivated area is situated on the left and 7/12 parts on the right bank of the great Menam. Now, the future increase of cultivated area I consider to occur in about the same proportion, so that about 5/12 of the total supply, i. e. about 310 $M.^3$, is required for the left bank, and about 440 $M.^3$ for the right bank regions.

For the left bank the capacity of the headsluice and the highest part of the main canal is fixed at once by the required supply of 310 $M.^3$ per sec.

On the right bank the required quantity is to be carried on, partly by the Menam Nawi and partly, as already mentioned, by the klong Makamtau, which klong carries the water to the Supan river.

The highest reaches of the Supan river are situated on a considerable ridge, have a sufficient capacity and are tolerably fit for carrying on the watersupply required for the whole part of the area to be irrigated at the west side of that river, and also for an eastward sloping strip of land along its east bank.

The region provided for by the Supan river, in this way, will be nearly half the total area under command on the right bank of the great Menam.

According to provisional investigations it seems most advisable to have the offtake by the headsluice of the klong Makamtau fixed at about 200 $M.^3$, whilst the capacity of the headsluice of the right bank main canal, that carries the water to the Menam Nawi, will be about 240 $M.^3$ per sec. (in the Supan area the proportion of land at present waste is greater than in the Menam Nawi area).

The area at present under rice cultivation amounts to about 40% of the entire extent of the whole area concerned and it may easily be expected that the area cultivated with rice may, in course of time, increase to 80% of the whole extent, for the area occupied by villages, gardens, waterways and roads, etc. being 20% already a considerable percentage in a fertile flat region.

The above proposed capacity of discharge of the headworks and main canals would allow an extension as large as 20% of the present area under cultivation; to allow the full extension of 100% above mentioned, the total quantity of water required would be about 1,250 $M.^3$ per sec.

Now it will be perfectly clear from the previous explainations, that a quantity of 750 M.^{3}, such as was proposed with regard to the present area under paddy cultivation and an extension of about 20%, is always available when required; and in all probability, the available quantity may be satisfactory also during a sufficient space of time for the above mentioned extension of the cultivated area to the double of the present extent, but the making of any scheme on that basis must be deferred till regular discharge determinations during some years have put the matter beyond all doubt.

The estimate however, that a quantity of 750 M.^{3} per sec. is available for the rice crop, is so strongly on the safe side that it will be in no way necessary to postpone schemes on that base, on account of want of regular discharge observations.

The capacity of 750 M.^{3} moreover will be quite sufficient to begin with, also in connection with extension of the area under cultivation.

It is even very probable that a much greater extension of the cultivated area than 20% will be possible with this supply, as will appear from the following considerations.

In the present condition of drainage of the paddy fields, most likely the quantity of water lost by infiltration into the soil, which else easily can be 1/3 of the total quantity required, will not be so important as it would be, when a proper system of drainage canals existed.

A proper drainage system however will cause such a great change in the methods of cultivation on a considerable part of the fields, as can only be achieved gradually in course of time.

As long as this process is still going on, therefore an irrigation system founded on the above mentioned capacity, will probably provide a sufficient quantity of water to allow extension of the cultivated area on a considerably larger scale than 20% of the present area under cultivation.

The extension of arable area moreover, will occur for the greatest part in the regions further upstream, for which it would be least difficult and least expensive to enlarge the capacity of the system, because the water required for extension in these tracts will be drawn off from the higher parts of the main canals.

Moreover it will not be particularly difficult afterward to enlarge the main canals entirely or to construct a second canal along side the first one, the less if this possibility is taken in consideration when the plans are being prepared.

Two parallel canals would even have a considerable advantage with regard to upkeep and management above a single one of double size and would not be very much more expensive.

The interest saved on postponement of outlay, if enlargement of the capacity is postponed till it is necessary, would certainly cover more than sufficiently the eventual extra expenses.

By the way it may be observed that outlay on future extension of the system in all probability could be more them recovered at once by sale of waste land rendered more accessable and suitable for cultivation in consequence of the extension of the system, as all waste land is the property of the State.

Another matter to be hinted at only is, that the weir and the other head works have to be constructed in order to stand a certain overcharge, which may be of great use on behalf of carrying on the silt to the fields, and to prevent silting up of the least rapidly running canals.

Main Canals. The further outlines of the scheme on behalf of the Lower Menam Valley, which will now be discussed, are determined by the natural situation of the plain.

During the time of full supply the water level in all the canals of the system, of course, must be raised above the level of the fields to be irrigated. On the main canals this may be 1 to 2 M. or even more, a high level in the main canals being able to contribute considerably to the velocity of the current in the distributaries.

The velocity allowable and obtainable in the main canals and distributaries is of course a matter of detail; but the soil being stiff clay, 1.20 M. per sec. will be about the maximun allowable in the main canals; in the lower parts of the main canals and in the distributaries this velocity however, in general will not be obtainable.

In the dry season, when chiefly only crops will be cultivated which have to be moistened but not necessarily to be inundated, the water level in the canals may be at equal height or even somewhat below the groundlevel, which will tend to diminish the loss by percolation, without causing inconvenience; moreover the surface slope in the distributaries in that season can be very small.

In accordance herewith, it is evident that the main canals should be constructed so as to have their level of full supply, about 1 to 2 M. above the ground level, whilst the dry season level may be about at the same height as the soil.

The main canals consequently will have their waterway partly in cutting, partly in embankment, and so the excavated channels will be comparatively small, and will be flanked by considerable embankments constructed of the excavated earth.

This method of canal construction is at the same time most fitted for the purpose and least expensive, the quantity of earth to be removed being comparitively small. The regularity of the slope of the Lower Menam plain will facilitate very much the general adoption of this principle of canal construction.

Where existing channels are to be improved and utilised as main canals, the improvement will consist chiefly in making embankments of excavated earth along them and in widening and regulating the beds.

To give an idea of the dimensions of the canals, it may be stated that the highest reach of the left bank main canals will require a bottomwidth of about 40 M. in the case of the velocity of the current being 1.10 M. per sec and the depth of water 6 M., at full discharge. Under the same conditions the bottomwidth of the highest reach of the Menam Nawi ought to bê 31 M. and of the klong Makamtau 25 M.

The upper reaches of the left bank main canals will require one or two small artificial falls, as the surface slope of the canal will be about 1/12000 and the slope of the ground is about 1/8000; in the case of the existing channels to be used as main canals, the windings in all probability will outweigh the excess of slope of the ground over the surface slope of the canals.

The alignment of the main canals will follow, as already stated, the ridges along the great Menam. On the right bank, as was explained, the Menam Nawi and the Menam Seekook will serve as a first right bank main canal as far as Bang Sam Koh; thus the greatest part of the first right bank main canal will require only a small outlay on improving these two existing channels, chiefly by making embankments, and on separating them from the great Menam by damming up with earthen dams the open connections and building a couple of navigation locks, in order to keep open boat traffic. Scouring escapes may be taken into consideration with regard to these connections.

The lower part of the right bank main canals, from Bang Sam Koh to Paklat south of Bangkok, about 65 K. M. long, has to be excavated, though for some parts it will be possible to utilize existing channels.

As however the width and depth of the main canals are continually decreasing in the downstream direction, because of the taking off of water by the distributaries, the lower parts of the canals are the comparatively least inexpensive parts.

The upper parts of the Supan river will act as a second right bank main canal and can obtain its supply, as explained, by the headsluice, the connecting-canal and the klong Makamtau.

The upper reach of the parts to be utilized of the klong Makamtau ought to be somewhat improved.

From the upper parts of the Supan river, the distributaries will be provided with water by regulating dams and distributary sluices.

Although the upper parts receive only a small quantity of local drainage water, the parts of the Supan river below about Bang Plama, must be kept free for discharge purposes, as the lower parts of the river are running, with only small ridges along its course, through the lowest parts of the plain between the high ridges of the great Menam and the Meklong rivers.

From about Bang Plama over Klong Ban Than down to Meklong (Samut Sang Kram) a Supan main canal, about 100 K. M. long, has to be excavated on the right bank of the Supan river, to provide with irrigation water the lower parts of the region under command. This canal most likely ought to have its course about where the area under command is limited by the ground growing too elevated. It will probably however be possible to utilize, at least provisionally, existing drainage and inundation channels to carry the water to some parts of the lower regions.

The most suitable direction of the Supan main canal cannot be determined except on the basis of efficient surveying and levelling.

The new main canal on the left bank of the great Menam, from the offtake to the mouth of the existing klong Lopburi at Ban Tahkwai, a distance of about 45 K. M., has to be located on the crest of the ridge near to the river. The site of this new canal will be especially suitable for scouring escapes.

From Ban Tahkwai the klong Lopburi can be used, which at present has a capacity of about 200 $M.^3$ per sec. This klong, in a natural or artificial way, is cut across the left bank ridge of the Menam and joins the Lopburi river.

The klong Lopburi must be improved, principally by the construction of embankments, in order to raise the capacity.

The Lopburi river derives the bulk of its discharge from the klong Lopburi and the united channel can be utilized for the main supply from Lopburi to Ayuthia. This channel however has to be improved considerably by enlarging the the narrowest parts of it, by cutting off windings, by making embankments, by damming up the open connections with the great Menam and building a couple of navigation locks etc.

From Ayuthia to Sumrong, below Bangkok, a distance of about 80 K. M., a new left bank main canal has to be excavated, though over some distances important existing channels can be made use of. From Koh Kert to Bangkok, this new canal can follow the existing canal Prem Pracha Korn. This old canal however will be of little use because it is nearly filled up with silt and moreover the original width and depth are much too small, even for the lowest part of the left bank main canal.

The left bank main canal in the vicinity of Bangkok, is pointed out for the offtake for a future town water supply.

This main canal, near Bangkok will have a capacity of at least 50 $M.^3$ per sec. and a minimum discharge, for dry season irrigation and flushing in the capital, of about 20 M^3 per sec. The average velocity in the waterway will be about 0.60 M. per sec. in the paddy growing season and 0.50 M. at minimum discharge.

As special care can be taken to keep the canal clean, it will offer a very suitable offtake for the town water supply, much better than an offtake from the great Menam, as this river, under the influence of tide, in the dry season to more than 60 K. M. above Bangkok, has not a continuous current and moreover receives all the refuse of the towns and villages on its banks, which remains stagnant or slowly running up and down at intervals, in its wide and deep tidal bed.

The Lopburi river, in the height of the rainy season has a discharge of some importance from its own catchment area, that seems to be fairly regular. When discharge observations of some duration show the last really to be the case, then this will enhance the possibility of extension of the cultivated area below Lopburi.

In general, discharge of drainage water in supply channels in the flat country of Lower Siam, particularly under the present drainage conditions, will not cause the disadvantage and trouble, which is connected with it in hilly regions, if only the matter is duly attended to on the plans, and in that case it may often produce saving of expenditure and in any case some increase of the available quantity of water.

The whole supply scheme, it must be observed, moreover does not often interfere in any important way with the drainage, neither of the area concerned nor of the outside regions. The Pasak river is the only important watercourse to be crossed, but further the main canals do not cross any general drainage line. These circumstances tend to reduce very considerably the cost of the works.

The ideal and final achievement of an adequate irrigation and drainage system is of course:

(1) to have the supply and drainage systems quite separated;

(2) to have all supply and drainage canals planned and carried out in the very most suitable way with regard to the purpose; and

(3) to have for each separate parcel of land the supply effected directly from a supplying ditch and the drainage conducted directly to a drainage ditch.

Only in case these conditions are entirely fulfilled will the cultivator be able to direct in the utmost adequate way the supply and drainage of each separate parcel quite at will, i. e. as appears to be most favourable to the momentary wants of his crop; and besides under these conditions they always will have water of the most desirable origin, that has not yet been used by, and has deposited already its sift for a great part on neighbouring fields.

There are however a good many reasons by which the endeavour to obtain these final achievements is impeded and often even made undesirable.

First of all the quantity of water available from other sources in many cases is not sufficient to dispense with the use of the local drainage in aid of the supply and in these cases separating supply and drainage entirely would of course be quite undesirable.

Secondly often financial considerations will tend to diminish the requirements of the systems, in order to be able to make use, as much as possible, of all kind of already existing works and channels, which in general will not be quite so fit for the purpose as if they had been laid out on a plan and constructed intentionally, but nevertheless will serve the purpose fairly well and reduce the expenditure considerably.

Finally in many cases, like at present in Lower Siam, the development of agriculture and the professional skill of the cultivators will be still unsufficient to utilize a thoroughly perfectionated irrigation and drainage system to its full value

The second and last reasons are of sufficient weight in the present case to decide on adopting the scheme in its proposed shape, keeping in view, however, its final aim at perfection.

As a matter of course, if there had been no existing klongs and the whole system of main canals, and distributaries also, had to be laid out upon a scientific plan, they would have been planned in some parts in another way. For instance the left bank main canal would not have been traced through the rather low tracts Lopburi-Ayuthia and new canals would not have been projected with the many windings, the channels to be utilized have.

The channels to be used as main canals and also the klongs in their functions as distributaries, of course, would have been more throughly appropriate when planned for the purpose, but as it is they will nevertheless answer the purpose very well and to use them will reduce the outlay very much.

Distributaries and klongs.

From the main canals are to branch off numerous main distributaries, in order to carry the water to the different parts of the area under command.

The existing main klongs, to a total length of at least 600 K. M., will of course be utilized for this purpose as far as possible, but for the greatest part have to be repaired and improved.

The rough embankments of excavated earth, already existing along the klongs, must be raised at many places by earth, dug out of the klongs for repair, and further must be improved and turned into proper embankments, fit to resist the head of water required to keep the waterlevel in the distributaries at a sufficient height above the groundlevel.

Where no suitable klongs exist, new canals must be dug. A system of another 600 K. M. new main distributaries is reckoned up.

The capacity of the distributaries of course depends upon the tract of land they have to serve and may be considered as a matter of detail.

The supply of water to the main distributaries is to be secured and regulated by a system of main distributary works, connecting the main canal, with the main distributaries. Further a number of navigation locks are required for boat traffic.

From the main distributaries the water is to be divided over subdistributary canals, for which purpose of course will be used the thousands of K. M. existing small klongs that are spread as a network over most of the cultivated parts of Lower Siam. Where there are no existing small klongs, it is considered that the local communities will make them in the way of cooperation, customary to the country. It seems fairly certain that people will do so, as under present circumstances they already dig a good many of small klongs for communication and scooping purposes only.

As far as people do not want immediately to make these small canals, a system of wide spread field to field irrigation will be adopted, as is generally in use in the rice growing deltas of the Madras Precidency (Buckley p. 254) and would be quite appropriated to the present agricultural methods in Lower Siam.

In order to secure full command of the water for the range of every subdistributary, a good deal of subdistributary sluices will be required, which will connect the subdistributaries with the main distributaries and where necessary have arrangements for boat traffic.

The most suitable and least expensive location of the new distributary and the subdistributary canals to be dug and of the distributary sluices to be built, can, of course, only be determined on the basis of efficient surveying and levelling, the available data about the elevation and the existing maps (the cadastral maps excepted) being more or less sufficient to trace the outlines of the scheme, but not suitable for any detailed plan.

The whole system of klongs must of course be separated from the rivers in order to prevent the water, carried by the irrigation canals, from escaping into the rivers and as boat traffic between the klongs and the rivers has to be kept open, the separation has to be effected by navigation locks.

The same will be the case for those different reaches of the new irrigation canals and existing klongs, which ought to have discontinued surfaces and are to be separated by artificial canal falls. In the flat Siamese plains these falls will however be few.

Locks to separate the water level of the klongs from the rivers will, as was explained (p. 26), even without supply be of great utility because of their function of preventing the water from running away from the fields, when the water in the rivers is still low or already subsiding.

Besides this they would at once also be of great utility to boat traffic, by keeping the water in the klongs at a higher level ; this would also facilitate scooping water on the paddy fields and nurserybeds.

Moreover the water in the lower canals will not so soon become and so long remain brackish, when the salt water from the rivers is prevented by locks from running freely in ; and finally the klongs will not silt up in the same way as they do now, because the locks will prevent new muddy and salt water from the river continually entering into the klongs and running away after having deposited a considerable part of its silt, as the tidal current now causes to be the case twice a day.

Relation between supply and drainage.

The final achievement of a fully elaborate irrigation system, of such a character that, for every locality the watersupply can be commanded quite at will, in its effect greatly depends upon the conditions of drainage of the said locality ; for if the supply actually is to produce the current and the depth of water on the fields at any time required for the crop, then it is, of course, required that all utilized and unnecessary water can be drained off at will from every such locality also.

For the fields in the highest parts of the area under command, the question of drainage can be solved very easily by draining off the superfluous water on the lower fields.

The fields which have an occasional shallow flooding of some days or a couple of weeks, as is the case with the bulk of the lands, would be in the same condition as the highest lands, except during the short period of occasional flood (as far as the irrigation works will not at once prevent the present flooding by the rivers), and would benefit by the supply combined with regular off-flow during all the rest of the time.

For the lowest parts, which under the present conditions are liable to a flooding of some considerable duration, the matter is however more complicated. As long as in these parts drainage is not fully commanded, they cannot be irrigated in the most adequate manner, i. e. have in every parcel of land, as long as they want it, the water flowing continually in and out.

These parts will therefore provisionally be supplied in a wide spread field to field way; that is to say the fields will be covered with water that has over whole region a continuous level, so that the small parcel-embankment (tamnop nah), where they exist, are submerged and the depth of water on the fields depends upon the elevation of the soil.

This method differs from the present flooding, in as much as the regular supply by irrigation will last as long as it is required and the water will be much more in continuous motion.

For these lowest strips of land provisionally the chief, but most important, difference between the present condition and the condition when supply is commanded therefore would be, that now for each part of the field the flooding lasts as long as the level of the rivers is sufficiently high to submerge it, (which generally is short enough indeed) and in the case of regular supply the flooding practically would begin as soon and last as long as may be required on behalf of the crop. Thereby in the latter case a great quantity of silt would be carried to the fields, though it will be dispersed still very irregularly.

An elaborate system of subdistributaries would of course be of no great use for the rice cultivation in these lowest parts, as long as no complete drainage is effectable.

By digging small ditches connected with the distributary canals, the dry season supply, however, could easily be made available for these lowest tracts of land, in order to irrigate dry season crops and to supply drinking water. These ditches would however be liable to be somewhat deteriorated every year during the flooding season.

There are of course no sharp limits between the highest lands, the occasionally flooded lands and the lowest strips; but only a nearly imperceivable gradual transition from one condition into the other can be stated.

Storage capacity. The storage capacity of the system is comparatively of little importance. The maximum storage in the riverbed above the weir up to Paknampo will be about 50 million M.^{3} in the dry season. About half this quantity, i. e. the water contained between the highest level and the depth of about 2 M., would be available for dry season supply, and this would provide about 10 M.^{3} per second during the period of a month. This quantity certainly would be of small influence on the supply from a river such as the great Menam, with a minimum discharge of about 200 M.^{3} per sec.

The storage capacity of the river above the weir, together with the water contained in the main canals and main distributaries (about 100 million M.^{3} at high level, and about 50 million M.^{3} at the lowest level available for irrigation) and in the subdistributaries and the deeply inundated tracts (as far as drainage will be still deficient) and with the quantity contained by some uncultivable beungs (swamps) will however have some regulating influence, especially at the end of the season of supply for paddy growing.

Drainage. Under present conditions of watersupply, draining the fields of superfluous water is practically entirely neglected; this circumstance is caused by the fact that in general there is no superfluity, but only shortage of water in the Lower Menam Valley and therefore an adequate drainage would tend more to aggravate this evil than to be of utility. The only effort actually made in the matter of drainage is, to prevent draining off of the water as much as possible.

The methods of paddy cultivation are shaped entirely in conformity with the requirements of the present conditions and even the paddy plants have assimilated themselves thereto in a most interesting way.

Nevertheless adequate drainage is of great utility to improve agricultural methods and results, as is generally known and has been already explained in the case of Lower Siam; but as long as shortage of water is the predominant impediment to a luxuriant development of rice plantations, of course, adequate drainage would, be more a disadvantageous than an advantageous expedient.

All this does not prevent the prejudicial consequences of want of adequate drainage being most obvious, in many regions in Lower Siam, by encroachment of rushy, reedy and other aquatic plants, which threaten to make some of the lower tracts quite uncultivable.

Although, as was explained, under the present conditions of agriculture in Lower Siam, want of drainage does not prevent watersupply being of the greatest utility, (as not only the bulk of fields but also the lower parts, where drainage is most deficient, will be greatly benefitted by it,) nevertheless as soon as an adequate watersupply will be available, and therewith shortage of water has disappeared, the want of a suitable drainage system will appear to be an impediment to further agricultural and social improvements in the lowest regions.

It is however, as was already hinted at, most probable, if not quite certain, that the quantity of water required for irrigation in the case of deficient drainage, is considerably less than when an adequate drainage is provided for, principally because in the last case not only the utilized water is drained off along the surface of the soil, but also a great deal is drained off through the ground to the drainage channels, which ought to have the waterlevel considerably lower than the ground.

The advantages of adequate drainage, here above explained, are:

(*a*) the possibility of increase of accomodation in the villages for men and for cattle breeding;

(*b*) the possibility of growing fruit trees and practising garden cultivation everywhere;

(*c*) the possibility of having the water on every parcel always at will drained off and supplied to the most required depth and having it never stagnant but continually renewed, which is of great value as well on behalf of the growth of the plants directly, as on behalf of the carrying on of fertilizing silt by the water, and so of the general improvement of the soil;

(*d*) the possibility of cultivating only the best kinds of paddy nah suan (garden rice) and of ceasing to cultivate the less valuable na muang paddy (floating rice);

(*e*) the possibility of making and maintaining roads at a reasonable expense.

These are of such importance and would so enormously change to the better the agricultural methods and the general aspect of the country, that in course of time the matter will certainly be provided for.

Drainage improvements however, it cannot be denied, are secondary to supply in Lower Siam and as the change in agricultural methods, connected with it, can only be expected to be possible by degrees, in course of time, the want of adequate drainage will also but grow gradually, and can gradually be provided for, at first there where it can be most easily adopted, and will be of the most striking direct effect, in order to make the people aware of the value of proper drainage and accustomed to the altered conditions of cultivation.

The principal agents of drainage in the Lower Menam Valley will be the lower parts of the Supan river for the regions on the right bank and the klong Bang Heer for those on the left bank of the great Menam, and besides some smaller drainage channels, which discharge themselves in to the main rivers or directly into the sea.

The great Menam and the Meklong and Bangpakong rivers, however, are situated too high on ridges and their flood level is too high to be of much avail for local drainage of the lower parts of the plains, except where they are subjected to tide.

The channels for local discharge in the lower parts are, of course, subjected to tide, which has the advantage of enabling, during some hours per day, drainage to a very low level, but the disadvantage of inundating some low parts with salt water, specially at high spring tides.

The difference between ordinary high tide and the very highest sealevel, it must be observed, is not very great in the Gulf of Siam (less than 1 M.). Considerable risings of the sealevel in consequence of heavy storms do not occur.

The very high tides occur rarely; but one inundation is sufficient to spoil the fertility of the soil for years, and great extents of land have been made uncultivable in that way.

As I have already mentioned, a good part of the evil in this direction has been caused by people concerned in shipping firewood and atap from the coast, by digging out the small creeks connected with the sea, in consequence whereof the tidal current in these channels has grown so strong as to be able to enlarge the creeks still more and carry the salt water continually higher up country.

The first thing to be done in the matter of drainage will be to prevent these salt water inundations (which principally in the case of the klong Bang Heer cause great damage to the fields,) by making tidal sluices that keep the salt water out of the inland part of the channel, or by making embankments which retain the salt water in the channel, when it remains in open communication with the sea.

The first means can be applied in the case of the smaller channels, the klong Bang Heer included, but in the case of big tidal channels, such as the lower part of the Supan river, only embankments are available.

The embankments of the Supan river however will only be of considerable dimensions at a few places where the soil is lowest, and will chiefly be formed by the earth excavated, in order to construct the principal distributary canals of the irrigation system, which, like the main canals, will run on the ridges along the banks of the river. These ridges indeed are not very high in the case of the lower part of the Supan river, but still of sufficient importance to be utilized.

The works on behalf of drainage will further consist in improving existing channels and excavating new ones, in order to obtain uninterrupted main drainage canals through the lowest parts of the regions concerned, and in making the level of this drainage canals independent of the level of the irrigation canals, by separating both kinds of channels by means of locks and sluices, and by aqueducts or syphons where they cross each other.

To the main drainage canals will be joined a system of tributary drainage canals and ditches.

The main drainage for the regions on the left side of the great Menam will principally run to klong Bang Heer and discharge into the sea by tidal sluices and for a smaller part to the lower reaches of the main rivers by canals, cut through the ridges there along and provided also with tidal sluices.

For the right bank regions the system of main drainage canals will run through the lower parts between the Supan river and the great Menam and between the Supan and Meklong rivers, which lower parts are situated rather near to the Supan river; at several localities canals are to be cut through the small ridges along the Supan river to effectuate the discharge, by separate tidal sluices, into that river, or existing channels have to be adapted for the purpose.

This system of draining the country by parts has the advantage of requiring only comparatively small drainage works and so being not very expensive, but can only be generally adopted in LowerSiam, when a big tidal channel exists near to the lowest tracts.

Some small tracts of land near to the coast will be drained by separate channels, provided with tidal sluices, directly into the Gulf.

The requirements of drainage, as already mentioned, will grow gradually with the changes in methods of cultivation, and so the whole system will be developed by parts successively; this will cause no engineering difficulties or extra expenditure of importance, provided that the final end is continually kept in view and the partial improvements are planned in accordance with the final end.

In connection with the accomplishment of the drainage for the lowest regions, the achievement of an elaborate system of subdistributaries for supply is to be continued.

Overflow of the rivers, when even rare and of short duration, of course, does not agree with an adequate irrigation and drainage system, and could cause considerable damage as well to the works and canals as to the gardens and paddy fields, the kinds of paddy that can best withstand high inundations then being replaced by more profitable sorts.

The embankments formed by the earth, excavated in order to construct the main canals and principal distributaries of the irrigation system, which, as was observed, will run on the ridges along the rivers, will however in principal already prevent this overflow, and where this not may be the case in course of time embankments will have to be constructed for the purpose.

These embankments will be neither high nor very expensive, being the banks of the rivers, as was explained, already raised to the level of ordinary high flood by natural deposits.

When overflowing is prevented by embankments, the highest floodlevel in the rivers will be raised of course, but evidently not very much because at present, though the vegetation and buildings on the banks of the rivers do not prevent the overflow at extraordinary high floods, nevertheless they confine the quantity of water escaping from the rivers to a very small part of the discharge.

The overflow in reality causes inundation only, but not a perceivable current on the submerged fields, because they are always quite overgrown with plants and offer so much resistance that no perceivable current is possible.

The discharge is therefore, even at highest floods, practically confined to the channels of the river, whilst the inundated tracts act only somewhat as regulating basins.

As the Siamese rivers, however, have already a very regular régime before they reach the lower plains, and rise and fall very slowly, the influence of regulating basins is neither very important nor much required; therefore preventing the overflow will not entail a considerable rising of high flood or require high embankments, a small rise causing already a considerable increment of capacity.

Some philosophers have disapproved embanking rivers, because this will prevent the lands to be further raised by overflowing. This may be in non-irrigated countries a point of consideration, but in the present case, as was explained, a much greater quantity of silt will be carried on to the fields by the irrigation canals, than overflow ever can do.

Moreover the Siamese cultivators have very great difficulty because of the fields lying too high, and compared therewith, but little because they are too low; and there is little reason to fear, that the contrary ever will be the case.

Navigation. When the proposed irrigation system is in operation, in the height of the rainy season boat traffic and rafting on the great Menam can go on nearly on the same footing as under present conditions. In the high floodseason the head at the dam will be small, so as to permit rafts and even boats to pass through the dam. By constructing a slide for that purpose, this may be continued for a considerable space of time each year. Further a set of locks will always keep open traffic between the up-and down-stream reaches of the river and the main canals, both for boats and for rafts; but as a matter of course the rafts ought to be arranged according to the dimensions of the locks, which may however be taken rather large.

In the dry season and in the commencement of the rainy season, the irrigation works will take off nearly the whole discharge of the great Menam and reduce it to a similar stream as for instance the Pasak and the Petchaburi rivers. Navigation with big boats of course, will not be possible on the nearly emptied river from the weir at Chainat to the reach of the river where the influence of the tides becomes considerable, which will be some kilometers below Angtong.

This will however for through traffic to and from the North cause no disadvantage, because the two main canals will offer much better waterways than the river does in the dry season.

That this must be the case needs no further explanation, when it is taken into consideration that the same quantity of water will produce a much deeper way in two comparatively narrow canals, than in the irregular, wide and shallow river below Chainat.

The troubles boat traffic at present has to contend with, during the dry season in these reaches of the great Menam are sufficiently known, so that I need not dwell on it in particular.

In the rainy season, at least for upstream traffic, the canals will also be preferable to the river, because of the current being less rapid; and moreover the way will be shorter.

The people concerned in boat traffic, and living on the banks of the river below the weir to about Angtong (where, in the dry season, the water level commences to become subject to the influence of tide), would of course experience considerable inconvenience with regard to big boats; small boats however will always be able to pass the Menam channel, because it will be necessary always to have some $M.^3$ of water flowing down the river, if only to produce drinking water for the population living quite close to the banks and for their cattle.

On the other hand however, as the system of canals will be greatly improved and extended and as all the canals will have, all the year through, a rather high level, the inland boat traffic all over the whole Lower Menam Valley will be under much more favourable conditions and so will be greatly furthered.

On the part of the great Menam above the weir, in the dry season, the effect of the dam will be to raise the level of the water very perceptibly to about

Paknampo and so the navigability of this part of the river, where at present in the dry season boat traffic has to go through many troubles, will be very much improved; consequently boat traffic always will be open between Lower Siam and the upper Menam plain.

Probable deepening of the Menam below Bangkok.

Another question of importance is in how far the offtake of the greatest part of the dry season discharge of the great Menam would prejudice the waterway from Bangkok to the sea for seagoing ships.

There is no doubt that the change in the régime of the river, produced by the offtake of water, will have some effect on the lower parts of the river, but in all probability, this effect will be an advantageous one, because the more water and silt is taken off from the river and carried on the fields, the less of the latter stuff will be deposited on the bottom of the river and on the bar.

With regard to this matter, it must be taken into consideration that, in the vicinity of the sea, the current of the river is slackened by the effect of the high tide, in consequence whereof always, the whole year through, during a part of the day a certain quantity of sand and silt is deposited on the bottom; but at the mean time by the ebb-current, the whole year over, during a part of the day a certain quantity of the stuff deposited is scoured away again.

In the rainy season most likely the deposit will be somewhat prevalent, and in the dry season the scouring away, because in the latter time the quantity of stuff carried down by the water is small.

When in the course of time however the bottom of a river shows no considerable change in depth, as appears to be the case with the great Menam, then in the whole the deposit and scouring out must of course have got to the point to balance each other fairly well.

If now the quantity of water coming down diminishes, the matter to be deposited will diminish in a similar proportion; the quantity of silt carried on being only dependent upon the discharge of the river.

The force of the ebb-current however is dependent both upon the quantity of water flowing in by the floodtide and upon the discharge of the river.

When now the discharge diminishes, this will be also of influence on the ebb-current, but not in the same proportion as the discharge has grown smaller, because *firstly* the discharge is only one of the factors upon which the ebb-current depends and *secondly* because, when this factor grows smaller, the other factor, the quantity of water flowing in by floodtide, increases.

The scouring force of the ebb-current will therefore, when the discharge and therewith the deposit diminishes, decrease also but to a much smaller proportion than the deposit; and for this reason it may be expected that the bottom of the river, as far as the effect of tide is felt, must have a tendency to grow deeper in consequence of the offtake of water for irrigation.

These considerations are examplified by the fact that the lower parts of the Supan river, which has practically no discharge of any importance since the klong Makamtau has been silted up, keeps its channel open at a great depth, and is always navigable up to Bang Plama, at about 100 K. M. distant, in a straight line, from the sea; whilst the Meklong river, which has a great discharge, a few K. M. above Ratburi, at a distance of about 30 K. M. from the sea, already begins to become too shallow for navigation in the dry season.

That in the case of the great Menam, and also of the Bangpakong river, the channels have a great depth to far up-country, thus is not owing to their discharge, but to the prevalence of the tidal currents.

In the case of the Bangpakong river, moreover, the process is facilitated by the fact that the water contains a much smaller quantity of silt, than that of the great Menam and of the Meklong, as may indubitably be inferred from its colour.

Tide observations and discharge determinations at Bangkok and Paklat have proved that, when the regular discharge of the Menam is about 3,000 $M.^3$ per sec., the ordinary daily high tide still causes an upward current in Bangkok for a short time, from which fact may be inferred that the offtake of about 200 to 750 $M.^3$, according to the season, will not cause any important change in the level or depth of the great Menam, as far as it is subjected considerably to the influence of tide. [In Bangkok the crosssection of the waterway measures about 2,800 $M.^2$ and at Paklat about 5,500 M^2, at high tide].

The quantity of mud annually deposited on the bar, however, will decrease by the amonnt of the silt which will be carried to the fields by the irrigation canals and, as the mass of water running over the bar, and therewith the scouring force, will diminish in a much smaller proportion than the mud, in course of time a slight decrease in height of the bar may be expected.

**The Menam
owing salt.**

Under present conditions the great Menam grows salt or brackish annually in the dry season during about 3 months and to about 30 K. M. above Bangkok. Occasionally, in consequence of very high tides, the brackish water runs up higher for some hours.

As was mentioned, the quantity of salt water, coming in by flood, in the future conditions will increase and in the dry season thus the water will become brackish for a longer period [probably for about 6 months, as now is the case with the Supan river], to a higher degree and to further upstream ; but certainly not further than to the reach of the river where under present conditions the influence of tide ceases to be felt considerably, that is to say to a good distance below Angtong.

That the river will grow salt higher and longer will cause no difficulty which regard to drinking water, as all the canals and klongs on both sides of the river will always contain a steady current of fresh water.

If a pumping station existed, taking off water for Bangkok from the Menam above the reach that now grows salt in the dry season, it would of course be affected, when the water grows salt to a higher reach, and would have to recur to the nearest irrigation canal for its supply.

Teaktraders also will of course have to arrange the storage of their logs in accordance with the change.

They might use the big basin above the weir for this purpose and float down the logs in small rafts or simply in the future, as under present conditions, take to the lowest reaches of the river, which will not grow salt. That there will be a reach of considerable length and depth, which will remain fresh, even when the discharge is reduced to some $M.^3$ and the influence of tide is still considerable, is shown by what at present is the case with the Supan, Nakon Nayok and Prachim rivers.

Other available rivers.

Besides the great Menam, its tributary the Pasak river and further the Meklong and the Bangpakong rivers are still available for irrigation purposes in the Lower Menam Valley.

In comparison with the Menam, these rivers however are of small importance and the total extent to be irrigated by these three rivers together most likely will never reach a fourth part of the total area of the Menam system, treated above.

In regard to these rivers and the adjacent regions, much less recorded information is available than about the great Menam.

The regions concerned are moreover under cultivation to a much smaller percentage and no great cities as Bangkok, or even Ayuthia, lie in these tracts.

It is therefore the more a matter of course that the scheme of the lower Menam plain should be taken up first.

For these reasons the other rivers mentioned will here only be taken into consideration very generally and in connection with the Menam scheme.

The Meklong river can be considered as entering the plain about Bang Mai. In the dry season the level of the river is several meters below the banks.

The Meklong river lies rather elevated. At Bang Pong, at a distance of 50 K. M. from the coast, the banks lie about 16 M. above the low water level of the sea, whilst Muang Prom, on the great Menam, at a distance of about 140 K. M. from the coast, lies 17 M. above this level.

In consequence of these considerations and of what has been mentioned before concerning the discharge, togther with the elevated situation of the river, it is obvious that the water of the river is to be utilized for irrigation of the plain to the east side of the river, only as far as the land is too high to be watered by the Menam system, and further is to be reserved for the plains on the west side of the river.

To get command over the water a weir has to be constructed across the Meklong river at a locality between Bang Mai and Bang Pong and further canals are to be dug on both banks.

The canal on the right bank has to be traced near to the foot of the hills to about Pechaburi. The Pechaburi river then remains chiefly available for the plain on its right bank.

On the left bank a canal is to be constructed in order to irrigate the most elevated parts of the plain, which lie too high to be irrigated by the Menam system. This appears, as must be deduced from the railway surveys, to be a strip of land adjacent to the river and about 10 K. M. broad in the vicinity of Bang Pong, but decreasing in breadth towards the coast.

Expecially in this tract numerous small inundation canals exist, which however are constructed very primitively; and in consequence of inadequate alignment, they do nearly as much harm to the lower tracts as they benefit the higher ones.

The area to be commanded by a future Meklong system may be extended to about 150,000 H. A.

The fields to be under command of the Meklong supply are at present almost entirely depending upon rainfall.

Rainfall is very scanty in these regions near the high western hill ranges, by which the monsoon rains are retained, and loss of crop here occurs more often than perhaps anywhere else in Siam, so that irrigation would be of the greatest utility. The population however is sparse and a small part of the land only is cultivated.

As the slope of the ground (about 1/5.000 below Bang Pong) is much greater than in the Menam Valley and the rainfall very scanty, the quantity of irrigation water required per unity of extent will be rather great here, and the area mentioned, in all probability, will be about the maximum extent that can be watered by the Meklong.

The dry season discharge of the Meklong river also being very considerable, this irrigation scheme promises to become a great success and follows in urgency and direct utility next to the Menam scheme.

It will however most likeky prove rather expensive, because scarcely any existing works can be utilized, whilst the capacity of discharge must be comparatively great and the situation at the foot of the hills will require expensive works to cross the ravines of the numerous rivers coming from the hills.

Drainage canals and protection against inundation by salt water of the lowest parts of the fields between Ratburi and Pechaburi will, in this case, require great attention, a great extent of paddy fields in this neigbourhood being deserted already, as people said, in consequence of inundation by salt water, by which a continually increasing extent of land, is rendered uncultivable.

This encroachment of the salt water is caused by small creeks having grown into big channels, by the action of the tides, after they previously had been enlarged artificially to facilitate boat traffic.

To check the continuation of this evil and to regain the lost land is a matter to be considered immediately, as well as the improvement of the existing inundation canals from the Meklong, which also would not be very difficult, in connection with the fairly rapid slope of the ground.

Around the town of Saraburi is a rather flat plain of the extent of about 100,000 H. A. which is too elevated (according to the railway surveys) to be irrigated by the Menam system and for which the Pasak river is the only available source for water supply.

The banks of the Pasak river have an elevation of 21 M. above sealevel about Saraburi and of 54 M. at Chaibadan, at 60 K. M. distance from Saraburi.

The considerable surface slope of the ground and of the river (about 1/2,000) secures the possibility of irrigation for the plain concerned, but indicates also that the quantity of water required will be rather great in consequence of the rapid slope and the considerable elevation above sealevel, though rainfall here seems to be rather greater than less than in the Lower Menam Valley.

It is therefore questionable whether the discharge of the Pasak river will be sufficient in quantity and regularity to supply the whole extent of the plain concerned. In any case, however, it can be considered as a matter beyond doubt that the plain concerned around Saraburi will be the maximum area to be reckoned upon for irrigation by the Pasak river.

When the whole lower Menam plain is properly irrigated however there is a considerable chance that rainfall will increase in the hills eastward of the valley and so the discharge of the Pasak river too, because the humidity of the air in the valley will increase considerably by the fact that the greatest part of a quantity of water of about 750 $M.^3$ per sec. more than at present will be evaporated, of which quantity most likely some part will be driven north-eastward by the south-west monsoon and condense into rain in the hills.

The scheme most likely will be much more expensive per unity of extent than the Menam system, because no existing canals can be used and the vicinity of hilly regions will require expensive works to cross drainage channels. For the present, only a small part of the land concerned is cultivated and the extent of this area would not justify great expenditure on important works.

For the future, by opening up new land, the Pasak scheme may be considered as promising great success, economically and also financially by sale of land.

The Bangpakong river and her northern tributary, the Nakon Nayok river, run through extensive plains, for which the discharge of the rivers can be made available.

Rainfall in these plains appears to be much greater than in the Menam plain, in consequence of the greater distance from the high western hill ranges and of the existence of considerable ranges of hills around the *circle* of Prachim to the north, south and east. In consequence of the important rainfall, the discharge of the rivers is fairly regular and large in proportion to the extent of the catchment area.

The clayey soil of the plain of the Prachim *circle* has a rather feeble slope as may be inferred from the slow current of the rivers; and the elevation above sealevel is small.

The quantity of water required for irrigation in all probability will therefore not be very great per unity of extent.

The plains however are very extensive, (at least about 400,000 H. A. seem adaptable for irrigation,) and the rivers concerned are the only available source for the purpose, so that the discharge of these rivers, however considerable and regular it may be, probably will be insufficient to serve the total extent that will require supply.

A scheme of irrigation would not meet with great difficulties here; drainage works and at some places, protection against undesirable flooding by the rivers are to be connected with it.

At present however in these regions there is no urgency with regard to irrigation, because they have a sparse population and only a small part of the plain is under cultivation; although an irrigation system constructed in order to open up the region, in all probability would prove a very paying enterprise.

The conclusion to be drawn from these provisional considerations with regard to irrigation from the rivers Meklong, Pasak and Bangpakong is, that these rivers at the best are in the position to serve their own adjacent plains and that it will not therefore be advisable to utilize them in aid of the supply for the lower Menam plain, which moreover, though certainly possible, would in all probability cause no saving of expenditure in any case.

Upper Menam plain.

The Upper Menam Valley, especially the upper Menam plain between Paknampo and Pitsanulok, has already been referred to.

This plain is very extensive but is little cultivated and has a sparse population, so that almost no rice is exported from the regions to the North of Paknampo, as I was informed (see footnote p. 80).

Irrigation will there be possible to a great extent, as far as regards the physical position of the soil, but is as yet not much required and certainly would not pay for the area under cultivation at the present time, because of the scarcity of cultivated land and population.

Irrigation works, constructed with the object to open up the land, in course of time, however easily may become a financial success.

In any case the matter must be taken into consideration with regard to the future.

In the first place, it must be stated by accurate observations during many years, in how far the extension of cultivated area, which can be expected in the lower Menam plain, will allow a considerable quantity of water to be taken off from the tributaries of the great Menam on behalf of the upper Menam plain.

The facts that the upper plain drains off again into the tributaries of the Menam and the probability that an extensive area under irrigation in the upper plain will tend to increase rainfall in the hills, and locally also, and hence increase the discharge of the tributaries too, are of course, very favourable to the possibiliity of water being available for the upper Menam plain.

Moreover, most likely it will be possible to increase the storage capacity of the enormous swamps in the Upper Menam Valley by regulating works.

Due care of the forests in the catchment area certainly will be also a valuable agent on behalf of the regularity of the discharge of the rivers.

In the narrow valleys of the upper parts of the tributaries, there are already instances of regular irrigation, as Mr. J. McCarthy states, in his book *On surveying and exploring in Siam* p. 121, with regard to the plain of Chiengmai; and in other valleys irrigation may be possible.

As these valleys are generally comparatively small in extent and drain off in the tributaries again, extension of irrigation in these regions would not tend so very much to the prejudice of the lower plains.

In any case, due attention must be paid to the question.

V.

SCHEME OF EXECUTING WORKS.

From the above mentioned considerations it is clear that with regard to urgency and utility of water supply, the lower Menam plain takes in every sense the first place.

On this basis is founded the whole working programme concerning an irrigation and drainage system, which I will now demonstrate.

Further this working programme is directed by the aim to obtain, within the shortest space of time and with the smallest outlay of money, the greatest direct results for the benefit of the people and financial returns for the Government.

To this end the most pressing wants are to be provided for in the first place and every part of the works has to be, as much as possible, immediately of direct utility as soon as it is executed; but in the meantime every subdivision of the work constructed must be in accordance with, and contribute to the final end, i. e. the construction of a thoroughly adequate system of irrigation and drainage.

In matters of irrigation and drainage works, next to the investigations about the available quantity and the quality of the water, the survey of the territory concerned is of the very first improtance.

The survey is one of the most weighty things with regard to an irrigation and drainage scheme, and refers here in the first place to the heights of the fields.

Insufficient surveys might cause great errors; though most errors in matters of irrigation works have not resulted from insufficient surveys but from insufficient knowledge about the natural and agricultural circumstances, the scheme had to deal with. It may be observed, that the most successfull irrigation works in Java, the Brantas deltaworks, as well as in British India, the Madras deltaworks, are those where least previous surveying has been carried out, which fact of course does not prove that efficient surveying is not wanted, but only that it is not impossible in many cases to employ it sparingly.

The aim of the surveys is to procure the records required for drawing up efficient plans and for judging the plans; of course, to prevent unnecessary loss of time and expenditure, the surveys have to be confined to what is strictly required for that purpose.

These requirement in the first place depend upon the intended works, and further on the natural features of the country and its previous artifical works.

In regions uncultivated or with undulating soil, where no other records afford reliable information, the special surveys for the purpose are the only available basis of the scheme and have to attain a most elaborate character.

In the case concerned, however, the scheme to be planned partly depends upon unmistakable natural features of the country, and further it is closely connected with the situation already existing, so that the general plan does not depend entirely on surveying, but surveying will serve principally for elaborating the plans.

This makes an enormous difference, because in the first case a general survey and leveling would have to be extended to and contoured plans finished of the whole area concerned, previous to any definitive planning being possible; whilst in the second case efficient special surveys or leveling of the parts most directly concerned, in connection with existing maps, records, and the physical conditions of the country, will suffice for beginning the planning and execution of the works. In the first mentioned case many years and millions would have to be spent in preliminary work without any immediate profit.

In the present case the cadastral maps (scale 1/4,000) which now already exist of nearly the whole cultivated area concerned, (in April 1901 already 3,380,450 rais had been surveyed) will be quite suitable and reliable for the purpose and spare a great deal of time and money.

These maps will only have to be extended and completed, as far as regards lands concerned, not yet surveyed, to begin where first required on behalf of the projects, and only so far as is quite necessary for the purpose, leaving further the survey of the fields to the Survey Department.

Further lines of levels will be run over the country 2 or 3 K. M. apart and where very flat perhaps more, to begin in those localities, where first required for the projects of the weir and the main canals; again a plan with levels and cross sections will be made of the reaches concerned of the great Menam, and of the Menam Nawi, the klong Makamtau etc. and further alignment plans for the new canals, firstly for the new left bank main canal.

The detailed projects will be planned on the base of these surveys by parts, as soon as the surveys are sufficiently advanced to fix the situation, height and dimensions of the works, in connection with the physical features of the country and the existing works by which the general outlines of the whole system are dominated.

The works required for improvement fo the existing klongs which will be utilized as main distributaries, must of course be in accordance with their future destination and thus are closely connected with the plans for the supply system; but the whole of these plans are to such a degree dominated by the physical situation, that these improvement works can be planned on partial surveys of the localities concerned.

In connection with the urgency and the direct utility (both on behalf of agriculture and navigation.) of these improvement works, apart from the supply scheme, these partial surveys and the planning and executing of the improvement works are matters to be taken up in the very first place.

In connection with the principles set forth hereabove, the progress of the works should be as follows :—

Improvement of the existing klongs.

The first thing to be taken up is the improvement of the existing klongs.

Planning and constructing locks is first to be undertaken, to separate the principal klongs in the lower parts of the Menam plain from the rivers and the sea, in order to keep up a higher water level, by preventing the water from running away into the rivers or into the sea, and to keep the salt water from the fields and, as much as possible, out of the klongs also.

The very first klongs to be undertaken are Pa Si Cherurn, Tamnern Saduak and San Sep, in order to obtain as soon as possible at least one always practicable through communication across the lower Menam plain, from the Meklong and the Bangpakong rivers to the capital. The fact that these klongs run through the most densely populated provinces of the country, and the last mentioned one is in connection with the klong Rangsit system and is affected in an unfavourable way by these works, recommend them the more to be improved in the first place.

In the second place it seems to be most urgent to build a tidal sluice for the klong Bang Heer, in order to prevent further inundation by salt water of the middle parts of the range of the klong Sumrong.

These works can be planned on the basis of local surveys and levels of the fields and observations concerning the highest and lowest waterlevel, so that the construction of these locks can be commenced without much delay, when only the requirements of the locks in respect to the future supply system are duly ascertained on the basis of the local circumstances and kept in account.

These locks will be of considerable direct utility to paddy cultivation, by retaining the water and bringing a great extent of fields in the lower plain into about the same condition as the klong Rangsit fields now are; that is to say, the period of time available for agricultural operations will be lengthened and the risk of failure of crop will be considerably reduced.

The reduction of loss of crop is so important, that in cases when in other regions the crop does quite fail for the greatest part, in the klong Rangsit region most of the crop is saved, though it mostly ripens prematurely and all at once, and so is of inferior quality and causes trouble in reaping.

In the dry season the locks and sluices will prevent the salt water from entering the klongs and they will remain fresh much longer.

Boat traffic will also directly be facilitated by the effect of the locks; but to make the klongs really practicable in the dry season, as soon as the locks are finished for a certain klong, the shallow parts of it must be dug out. The higher level kept up in the klongs by the effect of the locks will reduce greatly the quantity of mud to be dug out to make the klongs practicable at all times.

The earth to be excavated will serve to improve the embankments and convert them into proper dykes, which in the mean time will form towing paths or cart roads.

Digging out these klongs also will not require lengthy surveying and can be carried out without considerable delay on that account.

The excavation work must chiefly be done by canal dredgers, in order to prevent interruption of boat traffic and water supply by the klongs, and moreover, because in Lower Siam experience has proved this to be less expensive than digging by manual labour.

The financial requirement of the improvement of the existing klongs, according to provisional investigation and surveys, may by roughly estimated as follows:—

ROUGH ESTIMATE FOR THE IMPROVEMENT OF EXISTING KLONGS.

(Expenditure on technical staff and surveying not included).

Klong Pa Si Charern [32 K. M.], -	excavation and improvement	Tics.	50.000
	2 navigation locks - - - -	„	150.000
Klong Tamnern Saduak [44 K. M.],	excavation and improvement	„	50.000
	3 navigation locks (one midway)	„	200.000
Klong San Sep [75 K. M.], - -	excavation and improvement	„	400.000
	2 navigation locks - - - -	„	150.000
Klong Bang Heer, - - - - - -	1 tidal sluice - - - - -	„	300.000
Klong Lat (Petrew) [29 K. M.], -	excavation and improvement	„	200.000
	1 navigation lock - - -	„	75.000
Klong Prai Wet [53 K. M.], -	excavation and improvement	„	400.000
	2 navigation locks - - -	„	150.000
Klong Maha Sawatdee [29 K. M.], -	excavation and improvement	„	150.000
	2 navigation locks - - - -	„	150.000
Klong Sumrong [60 K. M.], - - -	excavation, cutting windings and further improvements -	„	500.000
	2 navigation locks - - -	„	150.000
Klong Mahachai [32 K. M.], - -	excavation and improvement	„	100.000
	2 navigation locks -	„	150.000
Klong Meklong [35 K. M.], - - -	excavation and improvement	„	50.000
	2 navigation locks - - - -	„	150.000
Smaller klongs - -	excavation and improvement	„	200.000
	locks and dams - - - -	„	300.000
Miscellaneous - - - - - - - - - - - - - - -		„	475.000
	Total ticals		4,500.000

The money to be spent on making locks and on further improvements of the klongs in the lower Menam plain, as a rough forecast, may be estimated at $4^{1}/_{2}$ million ticals, as is stated in the above estimate. (Tics. 17=1£).

This outlay undoubtedly will pay at once, and also the cost of further upkeep will be recovered directly, and, considering the enormous frequentation of the klongs, in all probability very richly, only by imposing small lock dues or tolls.

When the 20 locks and sluices to be constructed are passed on an average by 150 paying boats per day and the average fee is $^{1}/_{2}$ tical per boat, then the total amount to be collected would be tics. 547,500 a year. Considering the figures concerning the frequentation of the klongs, (see p. 58) this evaluation will appear to be fairly moderate.

Gain of time will more than counterbalance the expenses to which boats will be put on account of the tolls and fees imposed.

Supply system.

The preparatory work of the supply system for the Lower Menam Valley has to be commenced at the same time as the improvement of the existing klongs.

The preparatory work necessary is rather extensive and requires a considerable space of time.

Apart from the regular hydrotechnical observations to be started, in the first place the existing maps have to be completed for the purpose and lines of levels have to be run all over the country concerned, to begin in the higher parts.

As was mentioned before, to fix the exact situation, the dimensions and the level of the weir and dam and to plan this principal work and the head sluices, the parts concerned of the great Menam, the klong Makamtau and the Menam Nawi, with the adjacent tracts, have to be surveyed and levelled in detail.

The direction lines of the upper parts of the main canals, as far as they have to be newly constructed, must be pointed out provisionally and surveyed in order to be in a position to determine the alignment and plan the canals definitively.

Further the planning of the improvements of the Menam Nawi, and the klongs Makamtau and Lopburi requires detailed surveys of the parts concerned.

All this will take much time.

The surveying work for the supply system has therefore to be started at the same time with the improvement works of the klongs, to cause no longer delay than absolutely necessary.

Investigations about gathering stone and other materials for the weir can be started at the same time and the machinery required for building the weir and headsluices and digging the canals, has to be planned and ordered.

Probably within about two years the preparatory work can have advanced far enough to commence the construction of the weir and headsluices and the digging the main canals.

Building the weir and headsluices will probably take about 4 years.

When the detailed survey and levelling for the weir and the upper parts of the main canals are finished, this work has to be continued with regard to the improvement of the existing channels to be utilized as main canals, in order to plan the improvements required and the sluices and other works to be built, to separate the supply channels from the rivers.

As soon as the dam is ready the adjacent regions will be benifited by it; when the two right bank headsluices and the very short connecting canals are finished, and the existing channels to be utilized are improved, then the whole of the regions influenced by the Supan river, the Menam Nawi and the klong Pakaitelan will instantly profit of the then possible supply.

The Lopburi-Ayuthia regions will get the supply as soon as the upper parts of the left bank main canal are ready and the Lopburi klong and river are improved.

To hasten the supply to the Lopburi klong as much as possible, it may perhaps prove advisable to excavate the upper part of the left bank main canal provisionally only to the size required for the supply of the Lopburi-Ayuthia region only, or for the dry season capacity, and enlarge it afterwards.

In the mean time the tracts of the new downstream parts of the main canals must be levelled, and surveyed after which the projects for these parts of the canals and works can be made.

The execution of these smaller works has to be commenced when the weir and upper parts of the main canals are still under construction, in order that all the works for the main supply canals from the offtake to the end can be finished at full size with as short as possible a period between. This of course is desirable to have the works, during as little time as possible, only partly of utility.

When the surveys, levellings and definitive planning for the channels to be utilized and for the lower parts of the new main canal are finished, comes the turn of the distributaries for the most elevated parts of the area; and while the main canals are being finished, these distributaries have to come under construction.

Before the main canals are ready to provide the supply, the improvement of the existing klongs, mentioned on p. 111, must of course, already be finished.

As soon as the weir, the head works and the main canals are finished, for the whole of the lower tracts where now flooding, by the existing klongs, can occur for a considerable period, the watersupply will be secured at once from before the beginning of June, till after the end of January, in a much better manner than at present in the most favourable time of the most favourable year can be the case with the most favourably situated fields. By raising the level of the klongs successively at the commencement of the rainy season, the labouring of the fields can go on successively also, to begin with the lowest part, and so the cultivation will assume a fairly regular character.

Further, in all those parts of the area under command, which under present conditions lie too elevated to be flooded, it will be possible at once to irrigate in a most adequate manner, only by digging small subdistributary klongs, where they do not exist already, in connection with the main canals and distributaries; and if people do not at once dig these small klongs, a system of wide spread field to field irrigation can be applied.

In proportion as the supply becomes available, the whole area under command, i. e. the whole lower Menam plain, will become in a highly improved condition with regard to paddy cultivation, and also in respect to dry season supply.

During the dry season, as soon as the supply is carried into effect, the whole area under command will be highly benefited with regard to garden and dry-season-crop cultivation, with regard to drinking water and with regard to inland boat traffic, the klongs carrying fresh water to a high level all the year through.

The town of Bangkok also then will have always fresh, running water in the klongs connected with the main canals and scouring water in the street drains.

The people will be able to partake at once to the fullest extent allowed by the present agricultural methods, of the benefits of the supply system, without any alteration in their cultivation or other habits being required.

The full profit of the works, till this stage, will therefore be obtained with out the delay, which would occur if the people had previously to change their methods of cultivation or to adapt their habits to new conditions of watersupply.

What in the above mentioned stage of the works still is wanting is an elaborate drainage system; especially in the lower tracts midway between the mainrivers, where all the drainage water of the higher tracts is gathered; in connection therewith, an elaborate system of subdistributaries for rice cultivation is not immediately required in these lower tracts, but only dry season supply ditches.

Adequate drainage improvements, as was explained before, require people to change their methods of cultivation very considerably for the better in the tracts concerned; and therefore it appears most advisable, to achieve them only gradually, in proportion as the cultivators become aware of the profits connected therewith.

Cost of the supply system.

The total cost of this extensive supply system can of course not be estimated with exactness, as long as the surveys and levellings required for definite plans are not yet performed and the works duly planned.

Nevertheless it is quite possible to give a rough idea of the cost of the works, as an approximation of the probable expenditure connected with the supply system. Such an estimate is here given.

ROUGH ESTIMATE OF THE COST OF THE SUPPLY SYSTEM,

(Expenditure on technical staff and surveying not included).

		Cost, if excuted:	
		at full capacity	at reduced capacity.
Weir and dam at Chainat	Tics	6,000.000	6,000.000
Headsluices of the main canals at Chainat	,,	1,000.000	1,000.000
Headsluice Makamtau	,,	500.000	500.000
Upstream part new right bank main canal (1 K. M.)	,,	200.000	200.000
Upstream part new left bank main canal (45 K. M.)	,,	9,000.000	5,000.000
New part Makamtau canal (1 K. M.)	,,	200.000	200.000
Improvement Menam Nawi and Menam Seekook	,,	1,000.000	500.000
Improvement Lopburi klong and river	,,	2,000.000	1,000.000
Improvement klong Makamtau and Supan river	,,	500.000	500.000
Downstream part right bank main canal from Ban Sam Kok to Paklat (65 K. M.)	,,	5,000.000	3,000.000
Downstream part left bank main canal from Ayuthia to Sumrong (80 K. M.)	,,	7,000.000	4,000 000
Supan main canal (100 K. M.)	,,	7,000.000	
Distributaries (600 K. M)	,,	5,000.000	4,000.000
Miscellaneous	,,	2,600 000	2,100.000
[Tics. 17=1 £] Total	ticals	47,000.000	28,000.000

These figures are meant to give an idea of the financial requirements and, as the whole Report, are intended to be a basis of provisional consideration for the Government, on which might be decided, whether plans and estimates of the works are to be made; but of course they are not to serve instead of technical plans and detailed estimates.

When considering the cost of new works in any country, a comparison of the cost of important works which have already been executed in the country, with similar works in other countries is of course of considerable value.

Therefore it seems worth while to state here the following data concerning the cost of the Siamese State Railways.

The Korat Railway, normal gauge, has cost 19.8 million ticals and has a length of 264 K. M.; the cost per K. M. thus is tics. 75,000.

The Petchaburi Railway, narrow gauge, has cost tics 7.9 million and is 151 K. M. long; thus the cost per K. M. is tics. 52,000.

In Java the normal gauge railways have cost in average fl. 99,000 or tics. 139,000 per K. M. and the narrow gauge railways fl. 69,000, or tics 99,000, for the Eastern system and fl. 89,000, or tics. 127,000, for the Western system.

In British India, the cost of the normal gauge North Western State Railways (3,077 mills) has been in average Rs. 172,000 per mile, i. e. tics 121,000 per K. M. (Tics. 17=Rs. 15=1 £) and of the narrow gauge Burma Railways (1,178 miles) Rs. 92,000 per mile, i. e. tics 65,000 per K. M.

From these figures it must be inferred, that execution of works has proved to be comparitively cheap in Siam, notwithstanding wages are high, * so that probably higher wages are compensated by more labour performed.

With regard to the cost of the present scheme, the expenditure on the canals forms the predominant factor.

For the new upstream part of the left bank main canal, 45 K. M. long, I have reckoned tics 200.000 per K. M.

This canal will have a capacity at the head of 310 M.^{3} per sec. and the velocity will be about 1.10 M. per sec.

The canal is about half in cutting and half in embankment and is considered to require on an average the removing of about 160 M.^{3} earth per M. length.

The downstream part of the left bank main canals is calculated on an average capacity of about 80 M.^{3}, per sec., an average excavation of about 60 M.^{3} per M. length and an average cost of nearly tics. 90,000 per K. M.; and the downstream part of the right bank main canal on an average capacity of about 60 M.^{3} per sec., an average excavation 50 M.^{3} per M. length and an average cost of nearly tics 80,000 per K. M.

The Supan main canal is reckoned on an average cost of about tics. 70,000 per K. M., and an average capacity of 70 M.^{3} per sec and an average excavation of 50 M.^{3} per M. length.

No reduction has been made for parts of existing channels which, when improved, at some localities can be utilized for the downstream parts of the main canals.

The main distributaries, I have calculated on about tics. 8,000 per K. M., with an average excavation of about 12 M.^{3} per M. length.

Now I will state here first that the experience of the Royal Railway Department has shown the average cost of excavation by hand to be a little less than 1/2 tical per M.^{3} in Lower Siam.

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* Coolie wages in general are ¾ to 1 tical a day in Lower Siam.

When using machinery the cost of excavation is considerably reduced, at least by $^1/_3$, as the experience of the Rangsit Canal Company has proved, according to information obtained from the Chief Engineer of the Company.

As the canals to be dug, are half in embankment, they will not require very deep excavation, though the dimensions are considerable.

Nevertheless I have thought advisable to reckon the excavation at $^3/_4$ tical 1 $M.^3$ for the main canals and at $^1/_2$ tical for the distributaries.

Further, of course, there is the cost for the locks, sluices etc, included in the figures mentioned.

It may be worth while to state here, for comparison, the cost of similar canals in British India, as found in Buckley's book, page 250 and 272. Buckley states as follow:—[the calculations in K. M. and ticals I have added.]

Canals.	Length in miles. (p. 250)	Max. discharge capacity at head in c. ft. p. sec. (p. 272.)	Cost per mile in Rs. (p. 250.)	Maximum discharge capacity in $M.^3$ per sec.	Cost per K. M. in (tics. 17= 1 £= 15 Rs.)
Ganges canal	437	6·800	38·163	193	26 867
Lower Ganges canal	557	5·100	30·246	145	21.293
Orissa canal	252	6·058	36·642	172	25·796
Sone canal	367	5·955	27·976	169	19·695
Bari Doab canal	362	4·000	26·090	113	18·367
Sirhind canal	542	3·040	32·706	109	23·025
Sidhnai canal	58	1·500	5·962	43	4·197
Agra canal	109	1·500	40·309	43	28·378
Midnapore canal	72	1·400	48·828	40	34·375

With regard to distributaries the highest figure Buckley states (p. 254) is Rs. 4.500 per mile for discharge capacities of more than 1,500 c. ft. per sec., i. e. about tics. 3,200 per K. M. for capacities of more than about 5 $M.^3$ per sec. [sufficient for about 35,000 rais of paddy land.]

These figures are the actual cost of the canals, as Buckley states, the accessory expenditure on establishments, tools, surveys, supervision etc. not included.

For this accessory expenditure Buckley estimates 25 % of the actual cost.

A comparison of the above figures with the amount I reckoned per K. M. [tics. 200,000 for the upstream parts, and tic. 90,000, 80,000 and 70,000 for the downstream parts of the main canals and of tics 8,000 for the main distributaries] makes my estimate seem rather exaggerated.

Though I have the conviction that my figures are a good deal on the safe side, there is however no question of an enormous exaggeration, as the following considerations will show.

In consequence of the peculiar deltaic form of the area concerned and because the capacity is based on rice cultivation only, the main canals will be comparatively of a much shorter mileage than is the case with canals of the same capacity at head in long valleys where only a part of the fields are under rice crop, as most of the mentioned canals are; moreover the main canals here not do devide into main branches, as is often the case in connection with the configuration of the country.

Therefore the main canals are very expensive per unity of length, as the average capacity and size is very great, in comparison with valley canals which have the same capacity at head but a much greater mileage.

With the distributaries the same is the case.

Further the distributary sluices will as a rule be provided with navigation locks or arrangements, which makes them much more expensive than in the case of the Indian canals, where navigation arrangements are rare.

Finally it is taken into account that wages are high in Siam and that a great part of the materials must be transported over considerable distances.

On the contrary however, in Siam expropriation of land will not be expensive; the clayey soil appears to be not very difficult in handling as the experience of the Rangsit Canal Company has proved; only a very small number of bridges have to be made, as roads and railways are scarce; moreover the canals cross very few drainage channels, which will not interfere in an expensive way with the system as a whole.

The estimate of the cost of the weir and other headworks, is also strongly on the safe side, compared with the cost of similar constructions in other countries.

With regard to the head works it may still be observed that the river carries very good quartz sand, that there are quartzite hills in the immediate vicinity and that lime can be brought up by boats from the lime stone quarries near the Pasak river, so that nearly all the materials can be obtained in the country and at a moderate cost.

The above statement about the probable cost of the supply system also considers the possibility of the Government desiring, from financial considerations, to execute the works provisionally at about half the proposed capacity, with the aim to enlarge them successively, and use the revenue derived from the provisional works for that purpose.

This idea will afterwards be treated more amply.

Improvement of drainage.

The difficulties of drainage are concentrated in the lowest tracts of land between the main rivers, where gathers all the drainage water of the higher situated regions.

Though drainage, as has been explained, in Lower Siam is not the first improvement to be applied, the want of proper drainage will be felt before long, as soon as the now predominating want of supply is provided for. People in the lower tracts then soon will become aware of the advantages of proper drainage, by the experiences in the higher regions. The requirements of drainage therefore ought to be kept in sight continually when planning and executing the supply system, in order to make the whole system in accordance with its final aim: to form a thoroughly adequate irrigation and drainage system; the former achievement being impossible, without the latter.

As long, however, as the supply is not yet in operation, drainage works would damage people, by depriving them of the little water they have, instead of benefitting them; therefore it is not necessary to take up the drainage improvements before the supply is chiefly provided for; but the preliminary work, i. e. observations, surveying and the general planning of the drainage system, of course must be combined with the supply scheme.

Some drainage improvements of very direct urgency, as the construction of a tidal sluice at Bang Heer, are connected with the scheme of improvement of the existing klongs.

Gradual and partial improvement of drainage seems to be the most advisable way in the present case.

This manner of improvement will consist in gradually lowering the high-water-level in the rainy season in the lower tracts between the main rivers, by interconnecting, widening and improving the drainage channels, separating them from the supply system and, where necessary, providing them with tidal sluices.

Every lowering of the level of, for instance $^1/_3$ of a M., will prevent strips of land from being flooded in the ordinary field to field way and will bring them into regular irrigation.

For this purpose rice field embankments (tamnop nah) are of course required, to be able to retain the water on the parcels at the depth most desirable.

If people would not like immediately to make regular field embankments for every separate parcel, then they could take, to begin with, to a kind of basin system, somewhat similar to those employed in Egypt, by making small embankments for the whole of every strip of land, that is excluded from the ordinary inundation by any gradual lowering of the drainage level in the locality concerned. They then could irrigate such a whole strip at once in the wide spread field to field way.

The whole regularly flooded lowest tracts between the main rivers would in this way become divided in long and narrow basins, consisting of strips of land of about the same level, enclosed within small, chiefly almost parallel embankments. Every basin would then have a seperate level, which is the same over its whole extent, but which can be lowered or raised as appears most desirable, quite independently from the water level of adjacent basins.

It may certainly be expected that in a comparatively short space of time such basins would be gradually converted into parcels, and the basin embankments converted, from paths, which they would be at the commencement, into practicable roads.

As already mentioned, the construction of drainage works will be accompanied by an extension and enlargement of the system of distributaries and subdistributaries for supply for paddy cultivation in the lower tracts concerned.

Construction and improvement of embankments against occasional very high sea and river floods, where the embankments of the supply canals do not fulfill this function, may be considered as to belong also to the drainage works.

When the general supply system is in operation, a part of the annual revenue derived from it should be destined for improvements of drainage, and extension of the distributary system connected therewith.

In a period of a decade and at the rate a million ticals a year or so, the principal works easily may be expected to be entirely finished.

However the works can scarcely never be considered as to be finished for good, because a thoroughly adequate irrigation and drainage system always will be in course of extension and improvement in a progressing country.

For the system, as it developes, tends to develope agriculture by extension of the cultivated area, and by intensifying cultivation, where extension is limited. Development of agriculture, however, requires new extensions of the system and so reciprocal action will always leave a good deal of work to be done.

Observations and records for other schemes.

While the most directly required and most paying works in behalf of the lower Menam plain are in preparation and execution, the possibilities with regard to the rest of the country ought of course also to be kept in sight.

To be able to consider and to decide upon the possibility of drawing off a greater quantity of water from the great Menam on behalf of further extension of the cultivated area in the Lower Menam Valley, or upon taking off water from the principal tributaries on behalf of the upper Menam plain, will require permanent investigations as to the discharge of the Menam and of the principal tributaries.

To judge the extent that can be given to future irrigation systems fed by the Meklong, Pasak, Bangpakong and Nakon Nayok rivers requires also regular investigations in regard to the discharge of these rivers.

For future drainage schemes, regular observations in adequate places, as to the (seasonal and tidal) rise and fall of the rivers and the sea are necessary, by gauges that refer to a common level; the records without this being of little or no use.

To consider the necessity and the utility of irrigation and to judge the requirements of adequate drainage, regular rain gauge observations are indispensable.

For scientific study of the discharge of the rivers, the rain gauge observations must also be extended to the catchment areas of the rivers.

Experiments as to the quantity of water required for irrigation of different crops and under different conditions have to be performed to be able to base future plans on local data and records on the subject.

All these observations, as far as they are not yet recorded, should be started as soon as possible, because the principal function of their value, next to expert arrangement and control, is the number of years they have lasted.

The observations already made have to be performed more systematically according to fixed rules, and are to be regularly recorded under technical control, to further the regularity and accuracy of the observations and to find and redress faults and mistakes or, at least to prevent continuation of them.

The rain gauge observations, as they are now made, have to be efficiently extended and would become perfectly reliable in this way.

The river gauge and tide gauge observations now performed, are of no value for technical purposes, because of their total lack of regularity and system.

A number of suitable river gauges at adequate places have therefore to be established.

Most of the observations of river gauges could best be made at the gendarmerie-stations along the rivers, as most of these are situated quite suitably for the purpose, and the organisation of the gendarmerie in itself is an efficient guarantee for regular and due performance of the observations.

Performing discharge determinations of rivers requires previous training for the purpose and takes much time, so that it will require separate men.

It will be obvious that making, organizing, controlling and recording of these observations is an indispensable subdivision of a regular irrigation service.

Staff and surveying expenditure.

The preparation, the planning and the execution of the works mentioned above, will of course require a staff of experts, engineers and other officials, and moreover the planning of the works and the observations and the surveying precursory to the planning will require considerable expenditure, as stated herebelow.

ESTIMATE OF EXPENDITURE FOR STAFF AND SURVEYING.

Function of the officials.	Average total of the pay and allowances together per month.	Staff to start with.		Staff when works are in full swing.	
		Number of the officials.	Annual amount of money.	Number of the officials.	Annual amount of money.
Director General	Tics. 2,200	1	Tics. 26,400	1	Tics. 26,400
Chief Engineer or Assistant Director	„ 1,500	—	—	1	„ 18,000
Superintending Engineers	„ 1,200	2	„ 28,800	5	„ 72,000
Executive and Assistant Engineers	„ 700	5	„ 42,000	10	„ 84,000
Overseers	„ 250	4	„ 12,000	20	„ 60,000
Assistant Overseers	„ 100	2	„ 3,400	10	„ 12,000
Surveyors	„ 80	15	„ 14,400	30	„ 28,000
Secretary Chief Accountant	„ 600	—	—	1	„ 7,200
Accountant-Translator	„ 300	1	„ 3,600	6	„ 21,600
Draughtsmen	„ 100	6	„ 7,200	16	„ 19,200
Clerks	„ 40	8	„ 3,840	20	„ 99,600
Office boys and Messengers	„ 25	5	„ 1,500	10	„ 3,000
Total staff	.....	...	Tics. 142,140	...	Tics. 361,800
Travelling expenses	......	...	„ 25,000	...	„ 50,000
Survey expenses :					
Instruments, utensils, etc.	......	...	„ 20,000	...	„ 5,000
Coolie wages, etc.	......	...	„ 25,000	...	„ 40,000
Miscellaneous expenses (boats, stationery, office furnitures, etc.)	......	...	„ 37,860	...	„ 43,200
Total staff and surveying	......	...	Tics. 250,000	...	Tics. 500,000

In the above table are stated the numbers of the officials and the expenditure on staff and on surveying and other preliminary work (the tical reckoned at 17 to the pound sterling] as considered necessary to start with, and further the staff and the expenditure on surveying etc., as, by gradual increments will be required when the execution of the works is in full swing. Further particulars concerning the staff, etc, will be treated afterward.

The pay is considered to be the total amount, all kinds of allowances, except for travelling, included, which the officials on an average will receive.

The salaries and further allowancees of the officials are counted in principa on a similar footing as those of the officials of the Royal Railway Department.

The technical education of the Irrigation Engineers is of the same standard as of the Railway Engineers and for tropical irrigation, still more than for railways, special expert training and experience are required.

It is consequently of the greatest importance, especially in irrigation works, to engage the best expert men that can be obtained, the more because every irrigation plan is, still more than for instance a railway plan, an independent question in itself, one that requires an independent adequate solution; and it is still more difficult for non-experts to judge of the technical efficiency of an irrigation, than of a railway scheme, so that in matters of irrigation the non-expert Government depends to a still higher degree on the ability of the expert officials.

It is therefore certainly justifiable to put the pay of the irrigation officials on about the same footing as of these of the Railway Department.

nual financial quirements.

The execution of the works proposed will require expenditure (1) on account the improvement of the klong already in existence [see p. 111], (2) on account of the execution of the supply scheme [see p. 115] and (3) on account of the staff, and of the surveying and planning, precursory to the execution of the works (see p. 112)

The sums of money annually to be employed will be small in the first years, because surveying, observations and further preliminary work previous to the planning and the planning itself will require a long period of time.

The works to improve the existing klongs in the lowest part of the Menam plain, however, can be commenced very soon, though a great part of the first year will be required for recruiting the staff and for surveying and planning, so that it certainly not will be possible to employ more than ½ million of ticals in the first year, which amount is partly to be spent on one or two canal dredgers.

When in the second year and afterwards annually an amount of 1 million, ticals can be disposed of for improvement of the klongs, then these improvements may be finished in the fifth year.

As these improvement certainly will pay at once, the annual sum to be spent, will soon be counterbalanced by an increasing amount of revenue.

With regard to the supply scheme the first year will be passed in recruiting the staff, and further in surveying, levelling and other preparatory works, and, above the expenditure on staff and surveying, no amount of money of any importance will be required for the supply scheme in the first year.

During the second year the preparatory work will be continued and as far as possible the definite plans for the weir, the headsluices and the upstream parts of the canals will be designed; further, stone and other materials can be gathered and machinery for the work can be planned and ordered; but the whole expenditure on account of construction in the second year, in all probability, can amount not higher than to one million ticals.

The third year, it will easily be possible to employ up to 2 or 3 million ticals and in the following years 4 or 5 millions of ticals may be required, to have the work steadily in good progress.

I presume in the fifth or sixth year the weir and dam, the headsluices and the canals connecting the Menam Nawi and the klong Makamtau with the head-sluices can be finished and these channels can be so far improved, that the supply can commence.

By this time the work will begin to produce returns, and the money still to be spent will be counterbalanced to an increasing degree by the revenue to be derived from watersupply and boat traffic.

In the fifth or sixth year most likely also the upstream parts of the left bank main canal and the improvements of the Lopburi klong and river can be finished so far as to provide the Lopburi-Ayuthia region with regular supply, at least when the new canal is constructed provisionally to the dimensions required for that purpose only. This would increase the revenue derived from the works very considerably.

Most efforts will then be concentrated on the lower parts of the right and left bank main canals and on the Supan canal and the main distributaries.

In proportion as these works become finished, the extent of the area supplied, and also the revenue derived from watersupply and boat traffic, will increase.

Within about 12 yeares, in all probability, the whole supply system may be completed and in operation to the full capacity require·p

The following table may give a rough forecast of a programme concerning the probable financial requirements during the first 6 years of carrying out the improvements of the klongs already in existence and the construction of the supply system.

	Staff and surveying.	Improvement existing klongs.	Construction supply system.	Total per year.
1st. year	Tics. 250.000	Tics. 500.000	Tics. —	Tics. 750.000
2nd. ,,	,, 300.000	,, 1.000.000	,, 1.000.000	,, 2.300.000
3rd. ,,	,, 400.000	,, 1.000.000	,, 3.000.000	,, 4.400.000
4th. ,,	,, 500.000	,, 1.000.000	,, 4.000.000	,, 5.500.000
5th. ,,	,, 500.000	,, 1.000.000	,, 4.000.000	,, 5.500.000
6th. ,,	,, 500.000	,, —	,, 5.000.000	,, 5.500.000

In the first year the staff is to be recruited and probably will not be complete the whole year over, in consequence of which the sum to be spent most likely will be lower than the amount estimated for a full year.

In the 7th and following years, works may go on on the same footing as in the 6th year, until the whole supply system is finished.

If annually a greater sum than 5 million ticals should be available for the construction of the works, the work could go forward quicker, and be finished perhaps a couple of years earlier.

If the money available be less, then of course the progress of the work will be slower and the completion will take a longer period of time.

After completion, the supply system will only require expenses for management and upkeep and for gradual construction of adequate drainage works.

The greater part of the staff then can be transferred, to carry out the smaller schemes mentioned, which can be investigated and prepared amply during the execution of the great Menam system.

In the last years of the time of construction, the expenditure on the great Menam system will already be balanced for a great part by the revenue derived from it; and when the supply system is finished, further expenses for irrigation and drainage purposes certainly can be drawn entirely from the net revenue on irrigation.

Reduced capacity.

Should the amount of money required to carry out the supply scheme to its full extent in the period mentioned of about 12 years, exceed the sum the Government would be able to spend on the purpose, then it would not be impossible to lessen the original outlay considerably by provisionally reducing the capacity of the works.

In this case a provisional reduction of the dimensions of the upstream part of the left bank main canal and also of the downstream parts of both the right and left bank main canals, to about half the proposed capacity, and further omitting provisionally the Supan main canal comes first in view.

The supply in the rainy season would then not be quite what it should be, but nevertheless a great improvement would have been achieved, the quantity supplied being still equivalent to a monthly rainfall of 13 c. m., i. e. about $^2/_3$ of the actual average of the monthly rainfall in the three most rainy months of the year.

In the dry season the supply would be quite the same and of the same utility, (except of course in the case of the omitted Supan main cannal) as when the system was executed at once in its entirety.

The extension and completion of the work could then be defrayed by the revenue derived from the system in its condition of provisional execution.

In case the works are executed provisionally at reduced capacity and finished in the same period of about 12 years, then the sum annually to be spent on construction may be less by 2 millions, and reduced to about 3 million ticals during the time the execution of the works is in full swing.

The total expenditure on the system when finally complete at full capacity will however grow higher in the case of a provisional execution on a reduced scale, because the annual expenditure on account of the staff and surveying will be nearly the same, whether the works are executed at full or at reduced capacity, and will be required for a much longer number of years, whilst the enlarging of the provisional system will require an extra expenditure above the total amount of the previous savings on the works.

By keeping, where necessary, full account of the future enlargement during the provisional execution, the extra expenditure on the enlargement may be reduced considerably; this however would tend to raise the cost of the provisional execution, because some parts of the works then ought to be made at once at full capacity.

The profits of the supply for rice growing will, by execution at reduced capacity and at a smaller annual rate, not be obtained earlier than in case of execution at full capacity, and will besides not be enjoyed to their full proportion and to the full extent of the area; and therefore the benefit and revenue of course will be smaller.

But nevertheless the profits would certainly be of such importance as to justify imposing of watertaxes on rice growing in the regions concerned, whilst the revenue from water rates for dry season crops and the tolls and lock dues would be almost the same in the regions under command.

Revenue on account of extension of the area under cultivation of course scarcely may be reckoned up in case of execution on a reduced scale.

The net revenue derivable from the system at reduced capacity, will hower most probably be more than sufficient to provide annually about 2 or 3 million ticals for successive enlargement and completion of the system to its full capacity, and so open the way for extension of the arable area and improvement of drainage.

In general however, execution of the system at a reduced capacity appears to be not advantageous to the financial interests of the Government and will not be advisable, unless the State budget absolutely demands the curtailment of the annual amount to be spent, to about 2 millions of ticals less than the sums before mentioned (p. 125.)

A partial curtailment of annual expenditure could be effected by omitting provisionally the Supan main canal, which canal, and its distributaries, however, in all probability will prove very profitable by sale of land.

Provisional reduction of the capacity, in order to reduce the annual sum of money to be spent, is a measure that of course always can be resolved upon during the time of construction, when circumstances make it necessary to do so.

The only real advantage possibly connected with execution at reduced capacity would be, that the system could be provisionally finished and the supply realised some years earlier and profits (though as regards rice growing not to their full proportion) could be enjoyed earlier also.

This would be in the first place of great importance with regard to supply of drinking water in the dry season.

Though herewith the system would provide in the most stringent want, scarcely any revenue return may be expected on that account; from a financial and economical points of view, the sanitary side of the matter therefore is not the first point to be taken into consideration; but if nevertheless this side should particularly be attended to, then it would be advisable to construct provisionally canals of the capacity of dry season supply only.

In all probability it would not be very difficult to have such canals in workable condition at the time the weir and headworks can be finished, say in about 5 or 6 years. The supply at dry season capacity could then begin at once and the works could afterwards gradually be enlarged and completed.

In case reduction of the capacity is resolved upon to accelerate the completion of the dry season supply, the annual rate of expenses should of course not be less than by execution at full capacity.

VI.

MANAGEMENT, UPKEEP AND REVENUE.

The management and upkeep of an irrigation and drainage system, is quite as important as is the construction, because the results of the system are to a great extent dependant on them.

As long as no artificial means exist to regulate the supply and the retension of the water, there is no question of management, because all manages itself, as every one interested has to take the matter as good or bad chance may serve.

As soon however as there are any artificial means tending to improve the situation, the question arises how to use these means and different interests will try to do the best for themselves.

These different interests show themselves in all directions.

For instance, navigation prefers always a high and uninterrupted level, whilst paddy growing will require a level according to the height of the lands, i. e. an interrupted level in some cases, and in the time of harvest the cultivators in general will prefer a fairly low level.

When the level is uninterrupted over a long reach, in the case of ordinary flooding or wide spread field to field irrigation, the interests of the paddy growers will differ too. The men interested in the lowest lands will not want the level required for the highest lands. The requirements of the men who have to harvest are quite contrary to those of the men whose paddy is still in full growth.

The men whose paddy is partly mature, partly still growing will in a rainy period require a low level in behalf of the ripe paddy and in a dry one a high level in behalf of the still growing crop.

These examples show that the management of the level in a single klong reach is already a matter that requires great care and consideration; and at the same time that an elaborate system of works by which both the supply and the drainage can be commanded quite at will for every part of the area concerned, will be of great utility to meet every occasional want, by the possibility of which the total results of the whole crop would be greatly benefited.

Still more care and consideration is, of course, required when a limited quantity of water is to be distributed over a great extent of land.

But not only care and consideration is required, but also ability to consider the demands and requirements from a hydrotechnical as well as from an agricultural point of view; for not only the momentary interests of the cultivators have to be considered, but also the requirements on behalf of the upkeep of the whole system. This last general interest, as representing a most important agent in the production of the nation, may in many cases appear more important than some temporary individual interests.

The management is most closely connected with the upkeep of the works. Unskillful management of headsluices for instance may hinder the upkeep by causing obstructing deposits of sand in the main canals; may endanger the canals by overcharging them and so on as well as damage the crop by causing untimely inundations etc.

It needs no further explanation to show that the management and upkeep of irrigation and drainage works has to be in the hands of expert technical men, while at the same time, the interested cultivators ought to have every opportunity of making known their wants and requirements.

The most advisable way in the matter of management therefore seems to be, to put the general management and supervision of the entire system in hands of an expert official of the Government, assisted by expert assistants and to give the cultivators as much influence as possible in the local management.

The management of the irrigation works will commence as soon as any artificial means to regulate the water exist, i. e. as soon as a single set of locks are ready.

The direction of the management them must, as mentioned, be held by an expert Government official; but to be sure that the requirements of the interested cultivators are duly taken into account, for every separate klong, as soon as it is provided with locks, election or nomination, from among the cultivators or landowners and officials, of a committee to advise the directing irrigation official seems to be desirable.

As long as only locks exist and there is no regular supply, the management only regards the level to be maintained; but as soon as supply is secured, the principal klongs will assume the character of distributaries, and then the subdistribution of the supply over the subdistributaries or minor klong will become also a matter of care to the committee for each principal klong.

The raising of the water level in the minor klongs, when the supply is increasing at the beginning of the rainy season, will be a matter of special interest, as long as in the lowest lands adequate drainage is still wanting and the system of subdistributaries is little elaborate, so that these parts still must be irrigated in the wide spread field to field way or by ordinary flooding.

Successive labouring of the fields, to begin with the lowest, then will be necessary in these tracts and require successive raising of the level.

The redistribution in the ranges of the subdistributaries or minor klongs is also a matter of considerable, though local interest and it seems to be advisable to try to have this matter arranged as much as possible by local klong committees, elected or nominated from among the cultivators and local officials, under supervision, of course, of the expert Government officials and the principal klong committees.

These minor klong committees would also have to take charge, under the supervision mentioned, of the construction and upkeep of the works concerning their range and be empowered to receive a certain klong due from the cultivators concerned for that purpose.

To meet the expenses of big improvements which would be too great to be paid in one year, the Government should perhaps arrange to lend the money required to the local committees, to be repaid, with interest, by instalments.

The supervision of the expert Government officials and the principal committees has to prevent the local committees from doing or leaving undone such things as would damage or imperil the interests of other parties.

Such arrangements would not only free the Government from the expenses on construction and upkeep of the works of smaller importance, but also from the daily care of innumerable smaller interests, attention to which would require a number of officials, who would perhaps never get so well acquainted with the local requirements as the local committees themselves.

The Government, as proposed, would construct and maintain the main supply canals, the distributaries (principal klongs), and the head works of the subdistributaries, (minor klongs), and would of course decide what smaller canals are to be considered as minor klongs.

In drainage matters a similar division should of course be made.

According to what I saw on my travels in the Lower Menam Valley, it appears to me that it undoubtedly may be expected that the Siamese cultivator, who fortunately is not in subjection to powerful village chiefs, has sufficient independence and ideas of his interests, to make committees, as suggested, a success.

Moreover, cooperation by subscribing money or contributing labour to purposes of public interest, is customary all over the country,

The fact that landed property is individual in Siam and communal lands do not exist, will facilitate the matter, as every one now will share directly in the benefit obtained by common efforts.

Cost of management and upkeep.

Due maintenance of the system is of the highest importance, to prevent it from decaying, and to have it producing its full results.

The maintenance, as explained is closely connected with the management; both functions naturally have to be fulfilled by the same staff of officials, both on behalf of the works and to save expenditure on both accounts.

The upkeep will consist of:—

(1) Excavating, by dredgers, those parts of the canals where the current is slowest and silt is deposited, for instance in the branches necessary for navigation only;

(2) Annual repairs of the banks of the main canals and main distributaries;

(3) Annual repairs of the weir, the headsluices, the escapes, the main and subdistributary sluices, the navigation locks the tidesluices, bridges, etc.

The staff of officials, required for the supervision of the distribution of the supply and for the upkeep of the whole system, the existing klongs included, may here be considered firstly.

This staff may be estimated to consist of:— [per year].

1	Superintending Engineer, in charge, pay tics. 1,200 per month	Tics	14.400
3	Executive Engineers, one for each main-canal-area, average pay tics. 800 per month	„	28.800
2	Assistant Engineers, one for the headworks and one for the office of the Superintending Engineer, average pay tics. 500 per month	„	12.000
12	Overseers, average pay tics. 250 per month	„	36.000
4	Accountant-recordkeepers, average pay tics. 300 per month	„	14.400
50	Chief guards average pay tics. 50 per month	„	30.000
300	Canal; sluice; lock; and tollguards, etc. average pay tics. 30 per month	„	108.000
4	Draughtmen, average pay tics. 100 per month	„	4.800
5	Surveyors, average pay tics. 80 per month	„	4.800
15	Clerks, „ „ „ 40 „ „	„	7.200
	Stationary, office boys, etc.	„	10.000
	Survey expenses	„	10.000
	Travelling expenses and field allowances	„	15.000
		Total ticals	295.400

Brought forward - -		tics. 295.400
For handling the weir and 3 the headsluices	40 coolies.	
„ „ 50 navigation locks and sluices	250	
„ „ 30 main distributary sluices -	60	
	Total 350 coolies.	
at tics. 20 per month and per head, total		„ 84.000
Allowances, for handling about 300 subdistributary sluices, to men living in the vicinity thereof, average tics. 10 per month and per sluice - - - - - - - - - - - - -		„ 36.000
Miscellaneous expenses - - - - - - - - - - - - - -		„ 14.600
	Total ticals	430.000

The expenditure on maintenance of the klongs already in existence (see p. 111) can be estimated as follows:—

For excavation of silt, 1 dredger, working expense tics. 3,000 per month - - - - - - - - - - - - - - -	Tics. 36.000
For annual repairs of the banks etc. of about 600 K. M. klongs, on an average at tics. 50 per K. M. and per year	„ 30.000
For maintenance of about 20 locks - - - - - - - - -	„ 20.000
For miscellaneous works - - - - - - - - - - - - -	„ 14.000
Total ticals	100.000

The expenditure on maintenance of the new supply system can be estimated as follows:—

For excavation of silt, 2 dredgers, working expenses tics. 3,000 per month - - - - - - - - - - - -	Tics 72.000
For annual repairs of the banks etc. of about 600 K. M. main canals at tics. 100 per K. M. and per year - -	„ 60.000
For annual repairs of the banks etc. of about 600 K. M. new main distributaries at tics. 50 per K. M. and per year	„ 30.000
For maintenance of the weir and head sluices - - -	„ 40.000
„ „ „ „ about 30 navigation locks and sluices	„ 30.000
„ „ „ „ „ 30 main distributary sluices	„ 30.000
„ „ „ „ „ 300 subdistributary sluices	„ 30.000
For miscellaneous works - - - - - - - - - - - - -	„ 28.000
Total ticals	320.000

The total annual expenditure on management and upkeep summed up thus amounts to:—

Staff and coolies for management and upkeep - - - -	Tics.	430.000
Expenditure on maintenance of the existing klongs - -	„	100.000
„ „ „ „ „ supply system - -	„	320.000
Total on management and upkeep - - -	ticals	850.000

If now the whole system be credited with, one million ticals a year for management and maintenance, a sum of ticals 150.000 would be available for new dredgers, gross repairs and improvements etc.

Financial returns of the supply system.

The expenditure on the improvement of the existing klongs can be considered as to pay sufficiently in consequence of the revenue derived from navigation, as may be concluded from what was stated in this respect (see p. 111).

The supply system therefore will be considered separately with regard to the probable financial results.

The benefits of the supply system for every part of the area concerned are at once enjoyed, as soon as the supply is established; therefore it is quite equitable and fair that the cultivators who are benefited by the supply, should also at once pay for it, in order to return to the Government a proper interest on the expenditure incurred on their behalf, (roughly estimated at about 47 million ticals, exclusive of the expenses on staff and surveying) and to defray the expenses of upkeep and management of the system, for which purpose, as mentioned, an amount of 1 million ticals a year must be considered as amply sufficient.

When the weir and the headsluices and the short cuts to connect the headsluices with the Menam Nawi and the klong Makamtau are finished and the existing channels are improved, already a great area is benefited and could be called upon to pay.

As soon as the upstream part of the left bank main canal is finished as far as to be able to provide the supply required for the Lopburi klong and river, new extensive regions are benefited and might be taxed and so on.

When the main supply works are entirely finished, the cultivated area under command will be about $4\frac{1}{2}$ million rais and a water tax of one tical a rai, which certainly may be considered as fairly light in camparison with the profit the cultivators will obtain, would amount to a revenue of $4\frac{1}{2}$ million ticals.

In the area under command of the irrigation works in the Madras Presidency, where rice is also alsmost the only crop and circumstances, with regard and agriculture appear to be similar in many points to those in Lower Siam, an average watertax of 3.3 rupees per acre is paid, (Buckley p. 284) which is equivalent to about $1\frac{2}{3}$ ticals per rai, according to the rate of exchange of tics. 17=1£=Rs. 15.

In Java, the water tax is mixed up with the land tax. The landtax paid for non-irrigated lands is there generally about 1 tical per rai (fl. 3.00 per bouw). and for well-irrigated lands about 3 to 4 ticals per rai (fl. 8 to fl. 12 per bouw). The difference of 2 to 3 ticals per rai may chiefly be considered as an equivalent of the water tax.

A water tax of 1 tical a rai therefore will appear to be very moderate, the more as taxes in general are very light in Siam (see footnote p. 80) compared with other Asiatic countries. In the case of the Siamese cultivator, moreover, tax paying is by no means the same as sparing necessary food. For, the great extent of land they generally work, enables the Siamese cultivators to satisfy their wants very largely.

An extension of the arable fields with about 20 % of the present area or about 1 million rais, will most likely be arrived at within a few years after the completion of the system and such an extension in all probability would meet no difficulties in regard to the proposed capacity of the canals, even when an elaborate drainage system is achieved.

This extension, which, of course, in the parts of the area furthest upstream will be most considerable and is likely to commence as soon as the upstream parts enjoy the supply, would increase the annual irrigation revenue with another million ticals, or with nearly 1½ million, when putting the amount of land tax and water tax both to the credit of the irrigation works, as being the chief cause by which the extension is rendered possible, except in the klong Rangsit region.

Water rates for the use of irrigation water for second crop and for garden cultivation in the dry season could be a matter of consideration.

Further a very considerable amount of revenue may be expected from navigation tolls and lock fees in the new canals, the length of the new canals (about 1,200 K. M.) and the enormous inland boat traffic taken into consideration.

For 40 collecting places, (locks and sluices), each on an average passed by 150 paying boats per day, which pay on an average a fee of ½ tical, the annual amount would already exceed 1 million of ticals.

Besides by this direct revenue, the Government would profit also in a fairly direct way by the increase of the export of rice [duty and fees about tics. 3 per ton or tic. $^{11}/_{64}$ per picul] * and paddy and further by general increase of nearly all other headings of revenue, in consequence of the crop being greater and more regular.

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* The tical has a silver value of 0.60 Mexican dollar and is equal to 8 fuang, each worth 8 att; thus 1 att = tic. $^{1}/_{64}$.

To estimate the average increase of export of rice on account of the area already under cultivation at 4 million piculs and on account of extension of cultivated area at 2 million piculs, is certainly no exaggeration and this would already enhance the export duties and fees by more than 1 million ticals.

The revenue from water taxes, and on extension of cultivated area, tolls and lock fees and increase of rice export together (revenue from dry season supply not taken in account) might thus easily amount to about 8 million ticals a year.

This revenue, cost of upkeep and management (1 million ticals) deducted, certainly would be more than sufficient to pay a good interest and redemption on the original outlay, and moreover leave a million ticals or so per year for accomplishing the drainage works.

It may therefore be considered as beyond doubt that the expenditure on the supply scheme will prove to be of the greatest profit, not only on behalf of the people (the consideration that in a good year the export of rice represents a value of about 50 million ticals more than in a bad year (see p. 34), shows this most strikingly with a single figure); but that for the Government this expenditure also will be a most profitable investment.

Over and above the annual revenue, the Government will recover directly a considerable part of the outlay by sale (or rent) of land.

Uncultivated land in Siam is all property of the State and so the sale of the land, rendered more accessable and fit for cultivation by the canals, will be of great importance.

An extension of cultivated area of about 20 % or nearly 1 million rais, as is considered to be possible with regard to the capacity of the works, certainly may be expected with in little delay.

In all probability a great part of this extension will already be attained before the irrigation system can come into full operation, as an extension of about 400,000 rai can be expected in the klong Rangsit area alone (see p. 82).

If, however, the extension directly in consequence of the supply system, does not exceed half a million rais, then, by selling the land at ticals 30 a rai only, the Government would recover at once 15 million ticals of the outlay on the works.

If a further extension of cultivated area in the course of time might require enlarging of the irrigation system, then the expenditure thereon will most likely be refunded, at once with great profit, by the revenue derived from sale of land only, as will be easily understood.

VII.

ORGANISATION OF THE SERVICE.

To prepare, construct (and manage) irrigation and drainage works will require an organisation, in accordance with the scheme of executing the works and on lines as will be indicated here below:

Separate Department.

1. *A Royal Irrigation Department is to be established under the Ministry of Agriculture, on a similar footing as the Royal Railway Department under the Ministry of Public Works.*

In the foregoing parts of this Report, I have demonstrated that irrigation and drainage works are matters of the highest importance to the Kingdom of Siam for the furtherance of increase of production and common welfare and for the improvement of sanitation and communication.

From the importance of the matter for the common welfare it must be concluded that irrigation and drainage works also are of great weight to the Government; therefore it is a matter of course that in a progressive country with a very centralized Government like Siam, the State not only has to occupy itself seriously in the matter, but has to take the initiative.

As irrigation and drainage, including the management of the same, provide for a lasting and not for a temporary want, they require not only occasionally, when some accident or adversity happens, but permanently the interest and care of the Government. Therefore, and because measures taken at random in this matter, still more than in many other cases, are of a very temporary nature and, in proportion to the expenses, of very small utility, it will be advisable to create a permanent branch of the Government service, to take charge of irrigation and drainage.

This is the more desirable because the successful accomplishment of an irrigation and drainage system requires not only training and experience in a very special branch of technical science, but also a proper knowledge of the details of local circumstances, and of the agricultural, climatic and economical conditions of the country concerned. The latter can but be acquired by officials of a permanent service, who have constantly and systematically to deal with the matter to its full extent, and record their experiences for their successors, and certainly not by officials who only have to occupy themselves with the matter occasionally, for isolated measures. Hence it is evidently quite natural that, for the matter in question, Siam should have a special, permanent and expert branch of Government service, just as is the case in other countries under similar conditions.

As the matter is assuredly of no less importance than, for instance, Railways, Surveys or Mines, in the line of the Siamese Government Institutions, the irrigation service should be a special Department under the Ministry of Agriculture.

Sphere of activity.

2. *The sphere of activity of the Royal Irrigation Department should include :—*

a, *improvement of the existing natural and artificial, public (Government) irrigation, navigation and drainage works, canals and rivers ;*

b. *preparation, (by performing observations, by gathering records, by surveying and leveling etc.) and further planning and construction of new irrigation, navigation and drainage schemes ;*

c. *management of the water-distribution, the water-discharge etc. by the canals and works already in existence and those coming in operation, with the assistance of local Committees ; and further maintenance of all Government irrigation, drainage and navigation works and canals ;*

d. *collection, as far as feasable, of water taxes, water rates, lock dues, tolls and all other revenues, levied upon watersupply and works managed by the Department ;*

e, *supervision and inspection of the execution and maintenance of all kinds of authorised canals and works, connected with irrigation, navigation and drainage, which are executed or maintained by other authorities and corporations or by private persons and companies ;*

f. *advising on all plans concerning all kinds of works of other departments and of private persons and companies, connected in any way with irrigation, navigation and drainage channels and works, or with the offtake of water from the rivers or canals ; and on all applications regarding irrigation, navigation and drainage matters and works and registering of all concessions and grants in these matters.*

Concerning the sphere of the department to be established, the following explanations, are here given, being chiefly a recapitulation of what has been already explained in detail.

Improvement of existing works. a. The existing canals are, in general, in a very neglected condition and much in want of repairs and improvement, and as already under present conditions they are of great importance for navigation, inundation and drainage, their repairs and improvement is the first matter to be undertaken, both because of the direct utility of this work, and in regard to its connection with the supply scheme.

An efficient improvement, in accordance with the supply scheme and without useless expenditure of money, requires, of course, expert technical direction.

Preparing and construction of new schemes. b. Proposals for irrigation or drainage works must, of course, be founded on facts, stating;

that the present conditions cause damage and trouble and urgently require improvement (to state (which demands expert observation);

that improvement is possible with regard to the elevation of the lands, the rise and fall and the discharge of the rivers, the available and required quantities of water in different seasons and for crops, etc., (all of which is to be stated after expert observations, experiments and surveys);

that taking-off of water from the rivers or alterations of discharge by drainage works will not endanger other regions (which requires expert judgement of the hydrotechnical circumstances and interests of the whole of the area concerned);

that the estimated expenditure is in due proportion to the utility of the works, (wherefore expert plans and estimates are to be made).

In order to be in the position to take into consideration, at any time required, the possibilities of any scheme and to define its connection with other schemes and hydrographical interests, general observations and investigations must be performed continuously and records must be gathered concerning all those regions of the country which are adaptable for irrigation and drainage; whilst concerning the regions for which important works first come in view, the observation and investigation at once must assume a more elaborate character and enter into particulars.

The success of the works depends on expert construction nearly as much as on skillful planning; this is especially the case with works which have to resist the pressure of a considerable head of water, as is the case with most works connected with irrigation and drainage.

Preparing, planning and execution of irrigation and drainage works therefore should only be done under thoroughly expert direction. In the present case, it is a matter of course, that only the direction by experts in tropical irrigation will safeguard the Siamese Government from increasing the number of " monuments of bad engineering and wasted money " that have been the result of inept efforts in this matter in some other countries.

Management and maintenance.

c. As the stability of the works will depend principally on the planning and the construction, so the duration and the utility will depend largely on their management as well as on the upkeep.

The management, as well as the upkeep, requires continuous care and expert direction and control, in order to prevent, for instance, the works from being ruined by scouring out or the canals from being obstructed with sand and silt, and to secure the water being let in or drained off at the right time and having it distributed between the commanded lands in due proportion to the total quantity available, and the momentary wants for agricultural and other purposes.

It is a matter of importance that the Royal Irrigation Department should have in its hands all matters concerning water-management as far as is feasible, in order that the officials may gain proper knowledge about all what may cause damage and trouble or may be wanting in this respect, so as to be able to compare the urgency and utility of improvement in any tracts and make proposals for what is most necessary and most profitable.

The management, as well as the maintenance, of the irrigation and drainage works, the existing works included, should therefore to be put under the hydrotechnical department, as far as it is possible in respect to the staff of men to be disposed of.

The management of irrigation and drainage cannot be connected with the civil administration, even if the officials had sufficient training and practice in the matter, and time to spare for it, because the management of the entire sphere of a canal must, of course, be in one hand and the boundaries of the admistrative provinces and circles do not at all accord with those of the canal regions.

To leave the general management to the landowners concerned, would be still less advisable, because private interests will too often clash with each other.

Committees for the local management, however, elected or nominated from among the cultivators, landowners and officials, will presumably be of great utility towards the interests of agriculture.

Collection of revenue.

d. As far as is possible, without increasing the staff in a more expensive way than would be the case if the matter was assigned to another department, it will be advisable to have the revenue of the irrigation and drainage works collected by the officials of the Irrigation Department, because this will be the least expensive and best controllable way of collecting it.

Works connected with irrigation and drainage.

e. All kinds of works connected with irrigation, navigation and drainage canals and works, can easily cause serious difficulties. Inspection by the Royal Irrigation Department of the works, executed or maintained by other departments, that have any connection with the irrigation, navigation and drainage works, therefore should be provided for, to prevent damage being caused in that may.

The management and upkeep of the minor klongs, when assigned to local committees, has of course, also to be supervised by the expert Government department concerned in the matter.

Private canals are not only of importance to the concessionholders, but also to a large number of others, living in the regions concerned or in neighbouring tracts or having interests there. The land revenue in the regions concerned is also intimately connected with such canals. Therefore the Governmnet should supervise and inspect in how far the concessionholders fulfill their liabilities. Moreover the private canals and works, and the Government works generally will be dependent upon each other for their watersupply.

It therefore follows that the service concerned, by its very existence, is indicated to supervise the private canals and works.

Advising.

f. It can easily be understood that it is desirable to have the proposals and plans of other departments or private persons and companies, which in any way are connected with existing canals and works, advised upon by the Royal Irrigation Department as such works often can become impediments to irrigation, drainage or navigation purposes, or cause damage to previous rights and interests.

Plans and proposals concerning offtake of water from the rivers are, of course, included, because new offtakes may tend greatly to the prejudice of existing ones.

The same reasons that make advising on plans and supervision of already authorised works concerned by the Royal Irrigation Department highly desirable, viz: that the Government and third parties have great interests in these matters and that the watersupply of Government and private works are strongly connected with each other, make it also of great use to have expert advice on any applications for new private canals or other works.

Staff of the Department.

3. *At the head of the Royal Irrigation Department is to be placed a Director-General who, under the direct orders of the Minister of Agriculture, acts in all functions and disposes of all personal and material means assigned to his Department.*

The Director General shall be assisted by a technical and administrative staff, of such a number as cirumstances may require and as is sanctioned by the respective items of the State budget.

The technical officials cannot be charged with any work, not concerning the Department, without consent of the Minister of Agriculture and must abstain from all private technical occupations.

As the Irrigation Department is certainly of no less importance to the Kingdom of Siam than the Railway Department and many other Departments, it seems suitable that the chief of the Royal Irrigation Department shall bear the same title as is usual in Siam for the chiefs of such Departments.

The titles of the other officials (see p. 122) are conform to those commonly in use for technical services, as for instance in the Railway Department.

The number of officials required is dependent upon the speed required with regards to the surveys and plans and upon the sums of money, that annually can be placed at the disposal of the Department for construction of works, and when the supply commences, upon the extent of the lands already commanded.

To begin with, the Department should be divided into 3 divisions viz :—

I. The division for improvement, maintenance and management of existing works in the lowest parts of the Menam Valley, with a Superintending Engineer, in charge, 2 Executive or Assistant Engineers, 2 Overseers, 1 Assistant Overseer, 5 Surveyors, and Draftsmen, Clerks etc.

II. The division to start the initial work for the supply system, with one Superintending Engineer in charge, 2 Executive or Assistant Engineers, 1 Overseer, 1 Assistant Overseer, 10 Surveyors, and Draftsmen, Clerks etc.

III. The general division under the Director General, for the observations, the planning, etc., with 1 Assistant Engineer, 1 Overseer, (specially for the records of tide gauges, discharge of rivers, rainfall, navigation etc.), 1 Accountant-translator, and Draftsmen, Clerks, etc.

To begin with, the staff of officials thus will consist of:

1 Director General.
2 Superintending Engineers.
5 Executive or Assistant Engineers.
4 Overseers.
2 Assistant Overseers.
15 Surveyors.
1 Accountant-translator.
6 Draftsmen.
8 Clerks.

Within the space of some years, as works are going on and money will be available according to the requirements for executing them at full capacity (see p. 125), the number of officials must be increased considerably.

To assist the Director General in planning the principal works, a Chief Engineer or Assistant Director will be required.

The number of divisions and Superintending Engineers will be extended by 3, viz: the division mentioned (I.) will be divided into a right bank (of the Menam) division, and a left bank division, which will include the downstream parts of the two main canals for supply; the division mentioned (II.) will be divided into 3 other divisions, one for the upstream parts of each of the Menam main canals and one for the Supan works.

When the construction of works is going on according to what has been explained before, then the number of Executive and Assistant Engineers must successively be increased to about 10, and the number of Overseers to about 20 and so on.

The staff of officials, when works are in full swing, may be estimated at:—

1 Director General.
1 Chief Engineer or Assistant Director.
5 Superintending Engineers.
10 Executive or Assistant Engineers.
20 Overseers.
10 Assistant Overseers.
30 Surveyors.
1 Secretary-Chief Accountant.
6 Accountants (1 for each division and one accountant-translator for the head office).
16 Draftsmen.
20 Clerks.

The Director General, the Assistant Director or Chief Engineer and the Superintending Engineers all are to be fully qualified Civil Engineers, experienced in irrigation works; the Executive and Assistant Engineers may be partly not fully qualified practical Engineers of long experience and partly fully qualified young Engineers, the latter forming the material for new Superintending Engineers.

The Overseers, Assistant Overseers and Surveyors may be men of minor technical qualifications and will have to be trained up for the purpose.

When construction is nearing completion and supply is becoming general, commences, a part of the technical staff may be employed in the management, and the balance can be put on the drainage improvements of the Lower Menam Valley and on new schemes.

The pay of the staff is stated in the estimate of expenditure on staff and surveying (see p. 122).

For management and controlling purposes a staff of chief guards and of lock-, sluice-, and canal-guards will further be required, as the estimate shows on p. 131.

Training of the staff.

At the commencement a great part of the staff will, of course, have to be foreigners, as there are no Siamese trained and experienced in irrigation matters.

Even to fill the lower ranks of the staff chiefly with Siamese, will require previous training.

To have the lower ranks chiefly filled up by sufficiently trained Siamese and to make it possible in the future for Siamese to be charged with the higher technical offices, which require more technical training and experience, it would, I presume, be most desirable to establish a technical school, (of which the present Survey School perhaps may be considered as an existing basis) where young Siamese, who know how to read and write English, can be trained in mathematics and physics and the elements of engineering, with regard to the different branches of technical science practised in Siam, as house-, bridge-, and road-building, surveying, railways and, most likely irrigation works.

The most intelligent and industrious of the young men turned out, could, (when they show ability for the work), after some practise, be given a higher class of training to make them fit for higher requirements and from these could be selected the most promising ones to be sent to Europe to have high technical training and to become fully qualified Engineers, who after some years of practice and experience, may be able to occupy leading positions.

The Engineers of the different technical Departments, as far as attached to the head offices, would in all probabity be able to spare some time for teaching technical matters at such a school, which would relieve them from the trouble of training their men alone.

Appointment of the officials. 4. *All the officials of the Irrigation Department are to be appointed on the proposal of, or in agreement with the Director General, or by this functionary himself, as far as their monthly pay does not exceed 300 ticals.*

The Director General assigns the place of residence to the officials and transfers them.

The officials of the Department may not be owners of, or interested in any way in landed property within their official region.

It is a point of the highest importance to be sure, as far as possible to have only qualified and able men joining the Department; for technical faults of the Engineers can cause the Government and the cultivators the greatest loss or lack of profits.

As the Director General is to be made responsible for the work of the whole Department, he must be in the position to judge himself the capacity of his assistants and reject the men he deems not fit for the work. Moreover a sincere and cordial cooperation of the Staff with the Director General is in the first place required on behalf of the progress of the work and of the most useful employment of the men and moneys available.

More reasons will not be required to explain the necessity of the recruiting of his staff being chiefly in the hands of the Director General.

To secure the impartiality of the Department in its plans and management of so important a factor in the national welfare as irrigation, it is quite necessary that the officials are not interested in properties within the region where their labour may be of great influence on the value and production of lands.

Contracts concerning works. 5. *All contracts or agreements about supplies or works belonging to the sphere of the Royal Irrigation Departement are to be made through the intermediary of the Director General and payments thereupon are only to be given on evidence signed by him.*

The Director General ought to be consulted in all material matters of his administration, accounts included, as well as in the personal matters of his Department.

This is beyond all question required in any well organised and propertly conducted service.

Financial administration. 6. *The Director General disposes of the sums assigned in the State budget by the articles regarding his Department and accounts for the expenditure and receipts on a similar footing as is usual in the Royal Railway Department.*

As far as possible a fixed annual sum is to be set apart for the works of the Department.

A regular account of the expenditure on, and the revenue derived from the works of his Department, is to be kept by the Director General and stated in an annual report.

The Railway Department is here chosen as an example, because experience seems to have proved that the present arrangements for that Department are suitable and becanse that Department is in many points similar to the new department to be established.

As a great number of considerable and influential men in Siam are big landowners and the value of property is largely dependent upon irrigation works, a certain independence of action and administration will certainly contribute to the impartiality of the Department in question.

To designate, as far as possible, a fixed annual sum for the works of the Department will be of great importance for the regular progress of the work and the economy of expenses as well as for the stability of the staff of officials and of the labour which is also of great advantage to the works to be constructed.

That a regular account is to be kept with regard to expenditure and revenue on irrigation and drainage and mentioned in an annual report, needs not to be explained, this being an absolute condition on the part of the Government in order to judge of the results of the working of the Department.

Legal regulations 7. *Legal regulations are to be made concerning the rights and claims of owners and occupants of the lands, in matters of supply and discharge of water and of constructing canals and works; concerning water taxes, water rates, lock dues and tolls; with regard to navigation in the canals; against damaging of the canals and works etc., in connection with the existing laws and customs. The officials of the Royal Irrigation Department, as far as feasible are to be charged with the maintenance of these regulations.*

With a view to a regular and fair management of the watersupply and drainage matters, an inquiry into the present local rights and customs, in connection with the existing laws in this matter, will be necessary.

When the conditions of supply and drainage of the country are improving and the lands increase in value, questions bearing on these matters will grow in number and importance and to prevent, as much as possible, doubt in the decisions, legal regulations with regard to the rights and obligations in matters of watersupply and drainage will urgently be required.

The rights and obligations with regard to digging of canals by corporations and private persons is also a matter of importance to be settled is a legal way.

No less are penal regulations required, as far as they not exist already, to prevent people damaging the works; and to maintain this regulation lies naturally within the sphere of action of the officials, charged with the management and upkeep of the works.

* *
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Conclusion. The scheme of irrigation and drainage proposed in this Report and explained with regard to its possibility and utility embraces about $4^1/_2$ million rais of paddy-land, i. e. more than half the present cultivated area of the Kingdom of Siam.

The view of the scheme is: (1) improvement of the existing klongs; (2) construction of a supply system, consisting of a weir at Chainat, of 3 main canals (a right bank, a left bank and a Supan main canal, for all of which a great deal of existing channels can be utilized), with headsluices, distributary works and navigation locks, and of a system of distributary canals, with proper arrangements for watersupply and navigation. Drainage improvements will follow.

The existing and the new canals both all the year through, will contain a steady current and supply the water required in the paddy growing season and in the dry season, and moreover improve and open up navigation in the whole Lower Menam Valley.

Owing to the enormous extent of the area and the great weir and sluiceworks, the system will be a very imposing one and will contribute to the reputation of the Siamese Government.

Since the greatest part of the main canals and the distributaries, and especially those parts which are of the largest proportions and would be most expensive, will consist of existing channels and klongs, the system will be comparatively little expensive, (the total of the probable cost of the works being for instance but little higher then the expenditure on the town waterworks of Bombay only, £ 2½ million). Besides to a great extent the system can be soon in operation and produce results. The agricultural methods of the Siamese cultivators in general, moreover, are quite adapted to watersupply.

The expenditure on construction and maintenance will only for a small part be incurred on materials imported from abroad and will greatly benefit the Siamese stone, brick and lime industries.

Already during the execution of the works the Government will recover a part of the expenditure as taxes and duties paid by those employed in the construction.

The system is not, as would be the case with a railway, or road or a simple navigation canal, only of utility to some towns connected by it and to an adjacent narrow strip of country, but to the whole area concerned in equal proportion.

The utility of the system, thereby is not confined to communication only, and is not indirect and not a mere possibility in respect to national production, but the utility is as direct and as general as possible to the whole agricultural production of half the arable area of the country, because the system will remove the most serious impediment to agricultural development, as well with regard to rice as to other crops, namely want of water.

The loss of crop in consequence of drought, experienced over the area concerned of 4½ millions of rais in one bad year, will represent already a greater value than the total cost of the whole supply system.

The effect of the system will make life more comfortable and healthy for the people in the whole area concerned, and not less to their cattle, by providing them with fresh drinking water and enabling them to cultivate dry season crops, vegetables and grass or foddercrop in the dry season, and further with better and quicker means of communication; in its consequences the system will change the whole aspect of the villages by enabling people to surround their houses with well drained gardens, cultivated with vegetables, shady fruit trees, etc.

The density of the population in all irrigated countries shows most evidently that the sanitary conditions are favorable enough in irrigated regions.

In the present hydrographical conditions, during the parts of the year in which no agricultural work is possible, people are in want of occupation or are fetching drinking water; both of which promotes staying out of doors and visiting gambling houses.

The necessity of repeatedly removing from the fields to the riverside and vice-versa makes people unsettled, renders them unruly and prevents them from building suitable and healthy houses.

Bad years run the people heavily into debt. Many a man gets in not unfrequently recurring dry years only 1/4 to 1/10 of the usual crop of good years and even less, hence he soon is rendered quite unable to fulfil his liabilities.

Unsettledness, indebtedness and gambling most certainly carry robbery in their trail.

Constant agricultural occupation the whole year round, as a consequence of regular and adequate irrigation, will on the contrary incline people to peacefulness and promote order and will lead them to make their homes more comfortable, which will improve the sanitary conditions. *

The value of the land, and in proportion the national wealth of the country, will increase greatly in consequence of the increase in quantity, quality and regularity of the produce.

Even the poor lands, which people have been obliged to desert in consequence of inundation by salt water and incroachment of reeds and rushes, in course of time will become cultivatable and valuable again.

The possibility of extension of the area worked by one person will tend to a general extension of the cultivated area; and where extension is not possible to more intensive cultivation.

A great deal of the at present waste and uncultivable fields that will become fit for cultivation and accessible in consequence of supply and drainage canals, will be made arable by a part of the younger generation, immigrating to these tracts. This will prevent the chief drawback of the increase of agricultural population, namely the subdivision of the family holdings and moreover, return to the Government a considerable part of the outlay on the works.

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* To the following example (Buckley p. 250) may be referred :—

" The Swat river canal has irrigated far larger areas than were anticipated, and it has already proved to be a renumerative work. It was primarily undertaken. chiefly on political grounds, in order to settle the lawless tribes residing in the valley where the canal lies. "

The gradual development, from the present conditions, to retaining the water by locks, further to regular supply and successively to adequate drainage, in order to get continuously nearer to the final end: thoroughly adequate irrigation and drainage of the whole area concerned, will prevent all abrupt changes and difficulties with regard to the present agricultural methods, but tend to educate the people gradually to agricultural improvements.

The economical effects of the works will therefore not only be lasting, but in consequence of the gradual development of the system and of agriculture, will be continuously increasing

The financial returns on behalf of the Government will certainly not only defray the cost of upkeep and management of the works and a fair interest on the original outlay, but in all probability will also cover all further expenses required for accomplishing and extending the system and taking up new schemes.

Increase of national production and prosperity will inhance Government revenue in general, and particularly influence the receipts on customs, railways, posts, telegraphs etc.

The economical effects will certainly enable the Siamese nation to meet in a quite satisfactory manner the increase of wants and of imports that will accompany further progress.

At present the economical balance in relation to foreign countries is still satisfactory; but taking into consideration in what way progress is going on and wants are increasing and that extension of the cultivated area, under present conditions, cannot be expected to provide for the necessary increase of production, there appears to be a great probability that within the period in which the proposed works could produce their full primary results, the conditions will have quite changed and progress in Siam will become hampered by insufficient exports, when no efficient measures to increase the production are taken in due time.

With these general considerations I will close this Report.

(Signed), J. HOMAN VAN DER HEIDE.

Engineer of the Waterstaat of Netherlands India, temporarily placed at the disposal of the Siamese Government.

BANGKOK, JANUARY, 1903.

RAINFALL STATISTICS.

(ANNEXED TO THE GENERAL REPORT ON IRRIGATION AND DEAINAGE IN THE LOWER MENAM VALLEY).

RAINFALL IN BANGKOK.

(RECORDED BY THE AMERICAN MISSIONARIES.)

(Sir JOHN BOWRING'S SIAM, Vol. I. p. 400).

	1845. *inches.*	**1846.** *inches.*	**1847.** *inches.*
January	0	0.30	0
February	0	1.70	0
March	4.72	0.50	0
April	9 32	0.30	8.30
May	9.84	2.55	8.54
June	8.13	10.94	5.10
July	5.03	6.20	6.12
August	9.58	7 26	11.30
September	[18.66]	13.84	12.00
October	8 94	5.94	7.35
November	2.20	3.03	5.45
December	0.10	0	0
	76 52 *inches.* 194.36 c. m.	52 66 *inches* 135.60 c. m.	64.17 *inches.* 162.91 c m.

BANGKOK ARINFALL FOR 10 YEARS (1882-1891),

in

year	January	February	March	May	April	June	July
1882	0.50	0	0.21	4.52	5.92	3.78	8.43
1883	0	0.63	0	3.06	7.44	9,69	2.10
1884	(1st. January till 30th. June total of - - - -					7.00)	5.29
1885	0.10	3.62	0.12	1.35	1.52	8.88	6.78
1886	0	0.52	0.95	0.72	7.52	8.49	10.97
1887	1.79	2.25	0.87	2.39	8.76	4.19	7.97
1888	0	0	0	1.50	13.25	1.40	4.05
1889	5.10	0	1.15	1.04	6.97	5.81	3.88
1890	0.50	0.50	0	1.40	8.52	5.68	4.01
1891	0	5.80	1.62	0.46	1.33	1.77	4.54
Average in inches	0.88 for 9 years	1.48 for 9 years	0.55 for 9 years	1.83 for 9 years	6.80 for 9 years	5.52 for 9 years	5.80
in c.m.	2.23	3.76	1.40	4.71	17·34	14 02	14.73

For the year 1884 over the period January-June only the total, but not the monthly quantities are recorded. Consequently the total of the monthly average does not agree with the annual average.

REGISTERED AT THE OFFICE OF THE BORNEO COMPANY, Ltd.

inches.

August	September	October	November	December	Total per year in inches	Total per year in c. m.	ear
3.07	14.15	11.56	1.50	0	53.64	136.24	1882
5.76	8.57	3.44	1.52	0	42.21	107.21	1883
3.57	6.18	8.49	3.23	0	33.76	85.75	1884
10.96	14.12	9.06	3.35	0	59.86	152.04	1885
4.02	[16.41]	12.85	3.12	0	65.57	166.55	1886
8.75	9.61	6.98	1.56	0	55.12	140.00	1887
6.39	11.34	6.58	1.56	0	46.07	117.02	1888
10.64	[16.07]	11.14	6.76	1.51	70.07	177.98	1889
12.14	10.26	5.00	0.89	0	48.90	124.20	1890
5.29	7.10	6.93	2.53	0	37.37	94.92	1891
7.06	11.38	8.20	2.60	0.15	51.26	130.20	
17.93	28.90	20.83	6.58	0.38	Average per month in c.m.		

RAINFALL RECORDS OF THE

Places	year	January		February		March		April		May		June	
		days	c. m.	days	c. m.	days	c. m.	days	c. m.	days	c. m.	days	c. m.
Muaklek, *(in the Korai hill range 266 M. above sealevel)*	1894		No rec.		No rec.		No rec.		No rec.		No rec.	11	12.57
	1895	...	"	...	"	...	"	7	8.53	9	14.76	6	4.60
	1896	2	4.11	7	17.52	3	6.66	5	9.12	21	30.95	20	26.06
	1897	0	0	0	0	5	4.13	7	11.28	11	8.62	17	23.28
	1898	0	0	3	2.99	4	9.22	11	6.35	15	23.35	21	32.77
	1899	1	0.78	0	0	6	7.39	10	13.95	13	10.45	13	9.74
Average p.m.	...	...	1.22	...	5.12	...	6.85	...	9.84	...	17.62	...	18.17
Hinlap *(iu the Korat hill range, 220 M. above sealevel)*	1895		No rec.		No rec.		No rec.		No rec.		No rec.		No rec.
	1896	...	2.55	...	13.66	...	2.01	...	8.49	...	33.24	...	26.74
	1897	...	0.03	...	0	...	7.20	...	20.38	...	10.13	...	21.38
	1898	0	0	1	1.69	7	6.43	6	5.14	...	No.rec.	19	31.72
	1899	0	0	0	0	2	8:76	6	21.50	8	20.00	10	20.14
Average p.m.	...	...	0.64	...	3.84	...	6.10	...	13.17	...	21.17	...	24.99
Lopburi	1899		No rec.		No rec.		No rec.		No rec.		No rec.		No rec.
	1900	1	0 35	3	0.60	2	9.08	3	2.12	6	16.13	5	15.65
	1901	2	0.15	1	0.39	7	8.24	2	3.17	16	17.20	12	11.56
Average p.m.	...	...	0.25	...	0.49	...	8.66	.	2 64	...	16.66	...	13.60
Ban Pong	1900	...	No rec.	...	No rec.	1	1.75	2	8 26	9	20.73	14	14.10
	1901	0	0	2	1.20	2	6.70	1	0.25	9	9.67	9	7.67
	1902	0	0	3	6.25	3	4.50	5	9.87	9	16.20	...	No rec.
Average p.m.	...	...	0	...	3.72	...	4.31	...	6.12	...	15.53	...	10.88
Ratburi	1900		No rec.		No rec.		No rec.		No rec.		No rec.		No rec.
	1901	0	0	2	2.97	2	2.73	0	0	8	6.65	6	7.45
	1902	0	0	2	3.84	0	0	2	3.10	11	22.55	...	No rec.
Average p.m.	...	...	0	...	3.40	..	1.36	...	1.55	...	14.60	...	7.45

ROYAL RAILWAY DEPARTMENT.

July		August		September		October		November		December		Total per year, as far as there are no breaks in the records.
days	c. m.	days	c. m.	days	c. m.	days	c. m.	days	c. m.	days	c. m.	
17	24.28	24	35.86	15	26.84		No rec.		No rec.		No rec.	
8	9.73	17	25.52	17	27,75	10	7.21	0	0		,,	
13	15.63	17	16.52	12	17.03	12	30.26	4	2.87		,,	
18	20.16	...	No.rec.	19	29.59	14	25.72	4	3.73	0	0	
21	[42.95]	21	14.36	23	28,67	4	7.75	0	0	0	0	168.41 c. m. in 1898
	No rec.		No rec.		No rec.		No rec.		No rec.		No rec.	
...	22.55	...	23.06	...	25.97	...	17.73	...	1.65	...	0	149.78 c. m. Average per year (total of the monthly averages.)
	No rec.		No rec.		25.82	...	9.39	...	0	...	0	
...	19.86	...	29.60	...	20.60	...	30.61	...	5.55	...	0	192.91 c.m. in 1896
...	24.12	...	24.66	...	33.86	...	22.08	...	5.94	...	0	169.78 c. m. in 1897
22	[50.64]	20	16.02	11	25.04	4	2.35		No rec.		No rec.	
12	18.08	20	30.49	15	33.80	5	6.00	3	3.45	1	0.79	163.01 c.m. in 1899
...	18.18	...	25.19	...	27.82	...	14.11	...	3.74	...	0.28	169.23 c. m. Average per year (total of the monthly averages.)
	No rec.	20	14.99	23	[47.39]	6	1·83	4	4.34	0	0	
7	10.94	21	31.41	13	21.16	4	7.61	2	4.35	0	0	119.40 c. m. in 1900
17	11.13	27	18.35	16	25.25		No rec.		No rec.		No rec.	
...	11.03	...	21.58	...	31.36	...	4.72	...	4.34	...	0	115.33 c. m. Average per year (total of the monthly averages.)
10	10.55	10	11.99	16	27.76	9	23.37	2	2.84	0	0	
11	19.47	12	12.90	12	20.10	18	27.90	1	0.75	1	0.30	106.91 c. m. in 1901
	No rec.		No rec.	...	No rec.		No rec.		No rec.		No rec.	
...	15.01	...	12.44	...	23.93	...	25.63	...	1.79		0.15	119.51 c. m. Average per year (total of the monthly averages.)
	No rec.		No rec.		No rec.	9	20.55	3	3.40	0	0	
5	7.00	8	14.15	13	13.80	14	15.00	2	2.50	0	0	72.25 c. m. in 1901
	No rec.		No rec.		No rec.		No rec.		No rec.		No rec.	
...	7.00	...	14.15	...	13.80	...	17.77	...	2.95	...	0	84.03 c. m. Average per year (total of the monthly averages.)

RAIN OBSERVATION, REGISTERED AT THE

(AVERAGE OVER THE

(The Siamese year

Circle	April c. m.	May c. m.	June c. m.	July c m.	August c. m.	September c. m.
Payab (Chiengmai)	3.42	15.73	8.36	11.19	35.68	32.38
Pitsanulok - -	6.89	17.34	19.62	15.98	[44.18]	12.13
Nakon Sawan -	2.66	36.52	31.02	19.06	19.09	25.82
Petchabun - -	No rec.	No rec.	11.45	24.94	19.59	12.60
Average - - -	4.66	23.20	17.61	17.79	29.63	20.73
Krung Kao - -	9.08	15.80	14.75	12.83	21.38	22.82
Nakon Chaisi -	5.17	0	2.50	8.52	12.85	No rec.
Krung Tep - -	8.21	2.50	[44.09]	29.03	18.70	,,
Average - - -	7.48	6.10	20.44	16.79	17.64	22.82
Ratburi -	6.91	11.76	12.95	15.47	14.23	20.33
Prachim - - -	10.61	25.26	24.76	[47.52]	24 82	No rec.
Chantaboon - -	18.88	16.53	31.53	26.37	29.49	27.25
Average - - -	14.74	20.89	28.14	36 94	27.15	27.25
Sritamarat - -	6.17	5.76	11.87	10.12	8.63	16 21
Choomporn - -	10.30	38.91	24.34	14.01	10.32	9.54
Puket - - -	16.03	28.76	[41.22]	[54.31]	31.23	39.05
Average - - -	10.83	24.48	25 81	26.15	16.73	21.60

OFFICES OF THE PROVINCIAL GOVERNORS.

SIAMESE YEARS 117/120 (1898/1901.)

begins April 1st.)

October *c. m.*	November *c. m.*	December *c. m.*	January *c. m.*	February *c. m.*	March *c. m.*	**Remarks.**
No rec.	No rec.	No rec.	No rec.	No rec.	No rec.	The stated monthly quantities are averages of all the local records in the respective circles. Because of the numerous breaks and obvious errors in the local records, only in the form of the here stated averages these records may be reliable.
24.30	0.66	0.81	0.78	0.67	2.32	
21.78	No rec.	0.02	2.49	5.62	14.71	
24.09	,,	No rec.	0	0	7.96	
23.39	0 66	0.41	1.09	2.09	7.99	Average per year 149.24 c. m. *(Upper Menam basin.)*
16.48	3.24	0.02	0.63	0.01	8.14	
No rec.	0	1.26	0	5.09	No rec.	
,,	No rec.	No rec.	No rec.	No rec.	,,	
16 48	1.62	0.64	0.31	2.55	8.14	Average per year 121.01 c. m. *(Lower Menam Valley.*
26.09	2.06	0.00	0	5.22	19.26	134.28 c. m. *(Mek-) long plain.)*
No rec.	No rec.	4 36	5.18	0	[43.78]	
[43.55]	15.03	10.38	0.54	2.57	10.26	
[43.55]	15.03	7.37	2.86	1 28	27.02	Average per year 252.22 c. m. *(South Eastern circles.)*
17 90	36.76	17.58	20.22	5.53	16.05	
11.64	16.90	31 55	10 11	7.96	2.32	
[52.78]	27.14	3.35	4.52	0	5.04	
27.44	26 93	17.46	11.62	4.50	7.80	Average per year 221.35 c. m. *(South Western circles Malay peninsula.)*

RAINFALL IN KLONG RANGSIT.

(OFFICE OF THE RANGSIT CANAL COMPANY).

	1901. *c. m.*
January	2.05
February	1.23
March	5.19
April	6.60
May	12.14
June	13.96
July	25.54
August	18.45
September	37.96
October	15.11
November	4 59
December	—
Total in 1901.	142.82 c. m.

RAINFALL IN CHIENGMAI.

(BRITISH CONSULAR REPORTS.)

	1898. *inches.*	**1899.** *inches.*	**1900.** *inches.*
Janurary	—	—	—
February	—	—	—
March	—	—	0.33
April	3.82	3 44	3.19
May	8 02	8.03	6 40
June	4.10	5 35	11.21
July	7.34	4 32	11.52
August	11.27	7.80	13.63
September	7.58	8 38	[17.61]
October	0.39	0.50	4.10
November	—	2.04	2 17
December	—	—	0.60
Total per year	42.52	39.86	70 76

PRINTING ERRORS.

Page.	*Line.*	*Error.*	*Correction.*
2	14 from above	Swankulok riverd	Savankulok rivers
3	5 „ „	members	numbers
3	10 „ below	fairly a unifoun	fairly uniform
14	3 „ „	Govenment	Government
19	7 „ above	of	(*omit*)
19	10 „ „	only 3	only in 3
41	1 „ below	lowes	lowest
46	16 „ above	well an	well as
46	18 „ „	between main	between the main
51	5 „ below	conduct	conduit
52	16 „ above	water	(*omit*)
58	16 „ „	then	than
59	16 „ „	of land	of the land
70	17 „ „	canal	canals
72	11 „ „	decates	decades
73	3 „ „	Nan	Nam
76	5 „ „	east	least
77	2 „ „	a peesent	at present
87	7 „ „	canals	canal
87	12 „ „	canals	canal
88	7 „ „	rivers	river
93	15 „ „	over	over a
93	16 „ „	embankment	embankments
95	3 „ „	fields	the fields
109	12 „ „	fo	of
117	15 „ below	3040	3840
124	1 „ „	requireq	required
127	3 „ above	hower	however
127	16 „ below	them	then
133	4 „ „	regard and	regard to
135	11 „ „	with in	within
143	9 „ above	commences	(*omit*)
144	14 „ „	is	in

NOTES OF EXPLANATION

━━━━	Main Canals.
────	Distributaries.
- - - - -	Existing Channels to be used as Main Canals.
┼┼┼┼┼┼	Railways.
+ + + + +	Railways under Construction.
〰	Rivers.
═════	Existing Klongs.
▨	Area under command.
6·5	Heights above Ebb level of the Sea in Metres.